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METHODS FOR ROUTINE WORK IN THE EXPLOSIVES PHYSICAL LABORATORY OF THE BUREAU OF MINES

BY

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AND
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METHODS FOR ROUTINE WORK IN THE EXPLOSIVES PHYSICAL LABORATORY OF THE BUREAU OF MINES.

By S. P. Howell and J. E. Tiffany.

INTRODUCTION.

The methods now used by the Bureau of Mines for making physical tests and examinations in the explosives physical laboratory represent the result of more than nine years' effort in devising and improving laboratory routine to determine not only the explosives that are relatively safe for use in gaseous and dusty coal mines, but also those most suitable for use in metal mines, tunnels, quarries, and other engineering operations. This paper was compiled for the purpose of facilitating work in the explosives physical laboratory and not for publication. However, as the bureau is constantly receiving inquiries regarding the methods of testing used in its explosives physical laboratory, and as the results of the bureau's experience may be of use to explosives engineers and chemists and the manufacturers of commercial explosives, the paper is published for their information.

Reference should be made to other Bureau of Mines publications as follows: Bulletin 15,[a] Bulletin 66,[b] Bulletin 96,[c] and Technical Paper 169.[d]

EXPLOSIVES AND BLASTING SUPPLIES TESTED.

The work of the section is, in general, the testing of explosives to determine their permissibility for use in coal mines; the collection of field samples of permissible explosives and of manufacturers' samples of permissible explosives for test at the Pittsburgh experiment station, to determine their similarity to the explosives originally submitted for tests; the testing of other commercial explosives to determine their suitability for use in metal mines, tunnels, quarries, and other engineering operations; and also special investigations, at this station and in the field, of explosives and blasting supplies, to insure greater safety and efficiency in their testing, storage, thawing, distribution, and use.

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[a] Hall, Clarence, Snelling, W. O., and Howell, S. P., Investigations of explosives used in coal mines: Bull. 15, Bureau of Mines, 1911, 191 pp.

[b] Hall, Clarence, and Howell, S. P., Tests of permissible explosives: Bull. 66, Bureau of Mines, 1913, 313 pp.

[c] Storm, C. G., The analysis of permissible explosives: Bull. 96, Bureau of Mines, 1916, 88 pp.

[d] Howell, S. P., Permissible explosives tested prior to January 1, 1917: Tech. Paper 169, Bureau of Mines, 1917, 19 pp.

CONDITIONS GOVERNING TESTS.

The tests of explosives are made in accordance with the provisions of current schedules.

Manufacturers' samples of permissible explosives are also tested in order to obtain the bureau's authorization for minor changes in composition. No fees are charged for such tests; however, should the proposed change be considered a major one, then the manufacturer is required to submit a sample and to pay the same fees specified in the schedule.

PRECEDENCE OF TESTING WORK.

Tests for permissibility take precedence over tests of explosives for suitability, and no tests for suitability are made so long as any manufacturer is ready to have permissible tests made.

Tests for suitability are performed when no explosives are waiting for permissibility tests.

Tests of explosives for special purposes are made when no explosives are on hand for either of the tests mentioned above.

ORGANIZATION OF THE EXPLOSIVES SECTION.

EXPLOSIVES ENGINEER.

The explosives engineer has his headquarters at Pittsburgh, Pa., and directs all the work of the explosives section.

ASSISTANT ENGINEER.

There are usually two assistant engineers reporting directly to the explosives engineer. Only one of these assistant engineers attends to the detail work of the section (physical examination of explosives) and hereafter in these instructions this engineer will be mentioned only as the "assistant engineer." The other assistant engineer is usually engaged on special work.

TESTING ENGINEERS.

There are usually three testing engineers, either junior explosives engineers, junior chemists, or junior mining engineers; their number may be more or less than three according to the amount of work on hand. These engineers usually report to the explosives engineer through the assistant engineer and may report directly.

CLERK.

There is one clerk who usually reports directly to the explosives engineer.

SHOT FIRERS.

There are usually two shot firers; they are assigned work by the assistant engineer to whom they report. When assigned to work with a testing engineer they are subject to his orders.

DUTIES OF PERSONNEL OF EXPLOSIVES SECTION.

The explosives engineer is in charge of the section, directs the work, and prepares the letters, reports, and publications pertaining to the work of the section.

The assistant engineer directs and, where practicable, performs the following work:

Receives all explosives and blasting supplies, assigns key numbers to explosives, repacks explosives, collects samples for analysis, keeps a stock book of explosives, writes detailed descriptions of outer and inner explosives containers and method of packing, takes samples of coal dust and all blasting supplies and explosives to chemical laboratory for chemical examination, takes occasional inventories of supplies, issues detailed orders for hauling explosives, keeps account of the number of trips made by driver in hauling explosives, directs and outlines in detail the routine physical tests, checks and initials all routine test reports, attends to requisitioning of supplies, and assists the explosives engineer.

The testing engineers make all routine and special tests and assist the explosives engineer and the assistant engineer in the work outlined for them.

The shot firers charge the cannon when used in the test, care for the testing apparatus, assist the testing engineers, cast Trauzl lead blocks, and destroy surplus explosives.

The clerk does all stenographic and typewriting work required in writing letters and all preliminary and final reports of results of tests of explosives and blasting supplies, typewrites key cards from the note book of assistant engineer, keeps record of nonexpendable property, files papers in the technical files of the explosives section, and attends to all telephone calls.

PRECAUTIONS TO BE OBSERVED IN STORING, HANDLING, AND TESTING EXPLOSIVES.

GENERAL PRECAUTIONS.

1. Smoking is prohibited in or near magazines, in all buildings in which there are explosives, and near explosives.

2. Keep explosives away from sparks and open flames. Low explosives, such as black blasting powder, are particularly sensitive to flame or sparks.

3. Matches of the "strike anywhere" type should not be used or carried. Use safety matches only.

4. Do not leave explosives where they are liable to fall or be stepped upon. Do not drop explosives. Do not step on explosives.

5. The cutting of cartridges of explosives is prohibited except when they are in a thawed condition, and then only with a knife having a smooth even edge. The edge must not be of razor-like sharpness.

6. Metal tamping rods and metal-tipped tamping rods are prohibited. Use only wooden tamping rods, with or without leather tips attached with wooden pegs. If copper scrapers are used they must be faced with leather.

7. Horseplay is prohibited.

8. The quantity of explosives transported, stored, or thawed at one time or in one place should never be more than the quantity adequate for the purpose.

9. After using any explosive, the testing engineer must return what remains to its proper box and place the box in the magazine, or if the explosive is to be destroyed it should be placed in a box provided for the purpose.

10. Explosives must not be left about the buildings or grounds.

11. When cartridges of explosives are taken from a box their key number must be scratched on the wrappers with a pencil.

RECEIVING AND STORING EXPLOSIVES.

Boxes of explosives must be opened with a hardwood wedge and hardwood mallet, outside of the magazine, at a distance from it, and in a place protected from rain and direct sunlight. The use of such metal tools as a nail puller, hammer, hatchet, or chisel is prohibited.

Don't store detonators or electric detonators with explosives. A number of separate magazines are provided for the former.

Explosives should be stored only in the magazines furnished for the purpose; high explosives, including permissible explosives, and black blasting powder are to be kept in separate magazines.

Report promptly all broken, defective, or leaky containers for explosives to the assistant engineer who will take proper action to remove the menace.

Boxes of explosives must be stored so that the cartridges lie horizontally.

The floors of magazines should be regularly swept and kept clean. If the wood of permanent structures, such as the floor of a magazine, becomes stained with nitroglycerin it should be scrubbed with a solution consisting of one-half gallon of water, one-half gallon of wood alcohol, and 2 pounds of sulphide of sodium. A stiff broom, a hard brush, or a mop should be used, with plenty of the liquid so as thoroughly to decompose the nitroglycerin.

As a precaution against unlawful entry one key is used for all magazines; it must be turned into the office before the close of business on each day.

The ground around magazines must be kept clear of combustible materials, such as leaves, dry grass, stumps, and débris, as a precaution against fire.

When magazines are being repaired all explosives must be removed to a safe distance.

HAULING EXPLOSIVES.

Always keep the wagon box thoroughly swept.

The containers of explosives must be protected from the sun's rays, rain, etc. A large covered box or a canvas cover should be used.

Boxes must be arranged so that they do not shift.

Detonators and electric detonators must not be hauled with explosives.

Do not haul metal materials, such as tools and machinery, with explosives, detonators, or electric detonators.

Avoid as much as possible congested thoroughfares, street-car tracks, and dangerous crossings.

Do not leave any vehicle containing explosives unless the team is securely tied and the brakes set; if the vehicle is a motor truck the motor must be stopped and the brakes set.

Vehicles and harness used for transporting explosives must always be kept in first-class repair.

When a vehicle is being used for hauling explosives, it must be placarded "High Explosives—Dangerous."

If an automobile is used, the explosive must be locked in a compartment the inside surface of which is wholly of wood. The compartment must be as far as possible from the engine and effectively insulated from it. The engine exhaust must be pointed downward.

THAWING EXPLOSIVES.

Frozen or chilled explosives must be thawed or warmed in two-compartment thawers before use. Ordinary explosives containing nitroglycerin are likely to be frozen if the temperature is, or has recently been, as low as 50° F. (10° C.). The water used must always be heated in some other receptacle and transferred to the water compartment of the thawer. The water must not be heated in the thawer for there is danger of firing some of the nitroglycerin that may be left in it from the warming of a previous quantity of explosive.

The temperature of the water must not exceed 125° F., a temperature at which the water is not uncomfortable to the immersed hand. Never fill the water compartment unless and until the explosive compartment is dry, clean, and empty.

When explosives are being thawed, they should never be allowed to come in contact with water.

TESTING EXPLOSIVES.

The testing engineers must exercise every care in firing charges of explosives and see that no persons are close or in a dangerous position.

Notify teamsters that shots are to be fired; when firing shots in the open, ring the warning bell one minute before shooting.

When making gallery tests, blow the warning whistle and ring the warning bell one minute before a shot.

Notify occupants of adjacent buildings to have their windows open if the test may break windows.

See that no inflammable material is in danger of being set afire.

Metal parts of apparatus, such as the plungers and the anvil of the small impact machine, the disks and rings used with the large impact machine, and the shoes and anvils of the pendulum friction device, which come in contact with explosives shall be thoroughly cleaned with a suitable solvent after each trial in the apparatus in order to prevent the liquid explosive ingredient from remaining on the metal and becoming a menace. Acetone, which is suitable for removing liquid nitroglycerine, is the chief solvent.

When explosives are charged at the various pieces of apparatus, such as the cannons at the ballistic pendulum and the gallery, the testing engineer or shot firer who is charging the explosive must see that all switches are open and must not proceed with his work until he has in his possession the safety plug, thus insuring that the electric circuit is open. After the legs of the electric detonators have been connected to the firing circuit, the plug should not be inserted in the circuit until the charge can be safely fired, and then only immediately before firing. Many of the circuits used in tests by the Bureau of Mines are also provided with single-throw double-knife switches that are close to the blasting machine. Where live current is used these knife switches are used for completing the circuit.

Should a detonator or electric detonator fail to explode it should be properly labeled and retained for complete physical examination to ascertain the cause of the failure.

Electric detonators should be protected against all sources of electric current. A measure of safety is afforded by binding together the free ends of the legs of an electric detonator. Electric detonators should be so arranged when first taken from the box.

The explosive ingredients in detonators and electric detonators are sensitive to friction, impact, and flame, and the detonators must at all times be protected from such sources of danger. Hence, care must be taken in tamping charges containing these devices.

HANDLING MISFIRES.

GENERAL CONSIDERATIONS.

Misfires may be due to causes outside the bore hole or may be due to causes inside of the bore hole. Outside causes include defective contacts and insulation. Many short circuits are due to defective insulation. One cause of short circuiting is placing the cannon tightly against the end of the gallery. This trouble can be eliminated by the use of a short length of rubber tubing slipped over one leg of the electric detonator where the cannon face and gallery make contact.

The circuit-testing galvanometer can be used advantageously in locating many short circuits.

A misfire may be due to a defective blasting machine or to operating such a machine improperly. The handle should always be moved rapidly and forced down as hard as possible at the end of the stroke.

Within the bore hole the most common cause of misfire is a defective electric detonator. Before proceeding to handle a misfire supposed to be due to such a cause, *fifteen minutes* should be allowed to elapse to eliminate as far as possible the dangers from delayed shots or hangfires.

MISFIRES AT THE BALLISTIC PENDULUM OR IN TESTS 1 AND 3 AT GAS-AND-DUST GALLERY NO. 1.

The fire-clay stemming should be removed only by means of a pointed wooden stick with a cross section of about one-half inch. The fire clay should be carefully loosened and then removed by means of the special leather-faced copper scraper. Care should be exercised not to remove any of the explosive. However, some part of the face of the unexploded charge should be exposed and a new primer consisting of 2 or 3 inches of fresh explosive with an electric detonator embedded in it should be put in the bore hole, against the unexploded charge. The legs of the new electric detonator should be connected to the firing circuit in the usual way, and the charge fired.

MISFIRE IN TEST 4 AT GAS-AND-DUST GALLERY NO. 1.

Remove the primer and from it remove the electric detonator and insert a fresh electric detonator and proceed with the test in the regular way.

Should incomplete detonation occur in test 4, make up a primer, insert it in front of and against the unexploded part of the charge and fire into the gallery.

RECEIVING EXPLOSIVES AT THE PITTSBURGH EXPERIMENT STATION.

It shall be the duty of the assistant engineer to receive all explosives and have them delivered to some magazine.

EXAMINATION OF MARKINGS.

He should examine the markings on the boxes and ascertain the following:

1. Whether the explosive was consigned to the Bureau of Mines.
2. The brand name and from whom received.
3. The quantity received.

HOW TO ASCERTAIN PURPOSE OF SUBMITTING EXPLOSIVE.

Before assigning key numbers to the explosives, he should consult the correspondence relative to the explosives to ascertain the following details:

1. The application number, if the explosive is submitted for permissibility or suitability.
2. Why and by whom field samples were obtained.
3. The purpose for which blasting supplies are received.

QUANTITIES OF EXPLOSIVES OR BLASTING SUPPLIES REQUIRED FOR TESTS.

The quantities of explosives or blasting supplies required for the different tests are as follows:

Tests for permissibility.—At least 100 pounds of each explosive to be tested should be submitted in lots as follows: Twenty-five pounds in the smallest size in which the manufacturer wishes to market his explosive; 75 pounds in 1¼-inch by 8-inch cartridges, and 10 cartridges of any other sizes in which he desires to market the explosive.

Suitability tests.—Usually 50 pounds of each explosive is required, or the necessary quantity as determined by the explosives engineer.

Field samples.—These samples must be purchased and forwarded in their original containers. Their net weight is usually 25 or 50 pounds.

Blasting supplies.—The necessary quantity as determined by the explosives engineer should be submitted.

ASSIGNING OFFICE KEY NUMBERS.

The assistant engineer should not assign key numbers to samples of explosives until he knows the purpose for which they are submitted and only when the prescribed quantity has been received.

All explosives and blasting supplies submitted for tests, also explosives apparatus and materials used in making tests, are given

serial numbers known as the office key numbers. Each such number is prefixed by one of the following letters: B, indicating that the material is a black blasting powder; D, indicating that the material contains nitroglycerin; M, indicating that the material is other than that included under B and D.

The key card is the means of identifying adequately the material to which the number is given. The key card must show the information outlined below. This information must be stated fully in the notebook of the assistant engineer from which the key card is prepared. These cards are 4 by 6 inches; two original and two carbon copies are made.

NOTEBOOK FOR DATA FOR OFFICE KEY CARDS.

The information for key cards is entered in a notebook. One page is used for each number, and the information is stated under the headings in the order stated below:

In the upper left-hand corner of the page is given the office key-card number; for example, B–2010; D–2018 to D; M–2031 to G.

The numbers are marked on the ends of the containers with blue crayon. The box containing cartridges of the smallest diameter is marked, say, D–2018 and the boxes containing the next larger diameter of cartridge would be marked D–2018–A, D–2018–B, D–2018–C, etc. If there should be cartridges of still higher diameter these would be given succeeding letters; for example, D–2018–D.

A letter after a number may also be used to indicate different conditions in which the same material is received.

The headings used are as follows:

1. Manufactured by. (Give manufacturing company or companies and address.)

2. Brand.

   A. If explosive, give exact brand name, for example, Big Red No. 5.
   B. If electric detonators, state grade, length, and material of wires; for example, No. 6 electric detonator, 4-foot copper wires.
   C. If coal, state kind.
   D. If apparatus, state kind of apparatus.

3. Received from. (For example, the company above; for a field sample, the entry might be "purchased by H. I. Smith, of Urbana, Ill., from the Chicago, Wilmington & Franklin Coal Co., Orient, Ill., and shipped on Government bill of lading, delivered by Brown, bureau's teamster.")

4. Consigned to. (For example, Bureau of Mines.)

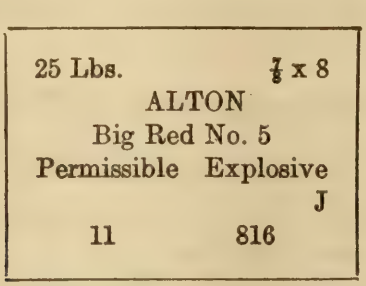
5. Delivered by. (For example, bureau's teamster; local teamster; company's motor truck.)

6. Date received. (For example, state date on which material is received at the experiment station.)

7. Quantity received. (For example, as below),

Five boxes as follows:
One 25-pound box, $\frac{7}{8}$ by 8 inches, denominated D–2018.
Three 25-pound boxes, $1\frac{1}{4}$ by 8 inches, denominated D–2018–A, B, and C.
One box, 10 cartridges, $1\frac{3}{4}$ by 6 inches, denominated D–2018—D.

8. Description on the end of the box on which the brand name is marked. Give a sketch, for example:



Description on end of box.

9. Purpose for which received. Should be designated in the manner shown below:

A. If for permissibility, should be designated "For official tests, application No. ———."
B. If for suitability, should be designated "Application S———."
C. If only a few suitability tests are to be made, examples:
"For special tests, application S–17."
"For propagation tests, application S–18."
D. If a field sample, so state.
E. If apparatus, give:
(*a*) Date of specifications in accordance with which apparatus was made.
(*b*) Drawing number.
(*c*) Order number.
F. If for detonators used in conducting official and suitability tests, state: "For regular tests."
G. Other purposes may be stated as follows:
(*a*) Special tests.
(*b*) To be used for Pittsburgh testing station standard 40 per cent dynamite.
(*c*) Laboratory samples.
(*d*) Special tests.

10. Check against. If the sample is to be checked against the original basic sample, give the key number. For example: "Check against D–852."

11. Markings on the sides, top, and other end of box should be stated.

EXPLOSIVES SENT TO EXPLOSIVES CHEMICAL LABORATORY.

Explosives are sent to the explosives chemical laboratory for chemical analysis, for stability and exudation tests, and for many other special determinations.

When a sample of any given brand of explosive submitted for official tests is sent to the laboratory for the first time the receipt card should be marked for "chemical analysis as per method 1."

Subsequent samples of the same brand should have on the receipt card "Chemical analysis, check against ———."

The receipt card for a sample submitted for any other purpose should show the particular purpose for which the sample is sent to the laboratory, for example, "Stability tests;" "Exudation tests;" "Determination of moisture."

QUANTITIES OF EXPLOSIVES REQUIRED FOR CHEMICAL ANALYSIS.

Each sample of explosive sent to the chemical laboratory for the first time should weigh at least 2 pounds.

Manufacturers' and field samples each require 1 pound.

As regards, detonators used for official test, four should be sent to the laboratory; otherwise, two.

METHODS OF RECORDING RESULTS OF TESTS.

ORIGINAL CARDS AND RECORD SHEETS OF TESTS.

The testing engineers record their observations on filing cards each 4 by 6 inches. Each record is in duplicate—an original and one copy. The cards have printed headings; each blank should be filled in either with words, figures, or a short horizontal line. In subsequent references to these cards they are designated test cards. Every conspicuous or noticeable fact about a test should always be noted and recorded. Test records are not necessarily complete when only the blanks are filled in. Testing engineers must check their tests when complete on the orders issued for making them and place in their files the next test number to be used.

Each test is designated by an index fraction, and great care should be exercised to record it correctly, legibly, and neatly. The numerator of the index fraction is the office key number of the material tested. The denominator of the index fraction consists of a letter and a number. The letter refers to the kind of test made, according to the following classification:

Significance of letters used in denominators of index fractions.

Letter in denominator.	Kind of test.	Page number of record sheet.
P. E	Physical examination	1
H	Unit deflective charge	2
G	Gas-and-dust gallery No. 1:	
	Test 1	3
	Test 2 (new)	4
	Test 3	5
	Test 4	6
S. G	Small gas-and-dust gallery No. 1	7
D	Rate of detonation by Mettegang recorder	8
DD	Rate of detonation by detonating fuse	8a
F	Length and duration of flame	9
I	Small impact test	10
J	Explosion-by-influence test	11
P	Pressure in own volume (gauge No. 1)	12
PP	Pressure in own volume (gauge No. 2)	12
II	Large impact test	13
C	Large calories	14
B	Small lead block	15
A	Trauzl lead block	16
AA	Small Trauzl lead block	16A
U	Pendulum friction test	17
P	Liters of poisonous gas and liters of gas	18
M	Miscellaneous	19
V	Burning tests	20
X	Storage tests	21
W	Crusher-board tests	22
N	Nail tests	23
FFG	Forbes field gallery	24
GGG	Gas-and-dust gallery No. 3	25
K	Rate of burning	26
S	Screening tests	27
T	Cone friction device	(a)
E	Photometer	(a)
L	Lamp gallery	(a)
R	Rescue apparatus	(a)

[a] Test obsolete.

The numbers in the denominator of the index fraction run consecutively, from 1 up, for each apparatus.

The page number is assigned to the test record sheets to facilitate filing.

Miscellaneous tests for which there are no forms should be recorded on blank cards 4 by 6 inches.

The index fraction of the duplicate must be identical with that of the original, as well as all other data contained on the card, and the copy must be legible.

Data relative to physical tests of samples of explosives and blasting supplies shall be sent to the computing room of the technical service section as follows:

1. Information, except that specifically mentioned below, regarding all tests shall be sent direct to the computing room in duplicate immediately upon being passed upon by the explosives engineer and initialed by the assistant engineer. It shall then be checked and initialed as correct or corrected by the computer in charge of explosives work in the computing room.

Upon receipt of data in the computing room, the test cards in duplicate shall be checked, reported, and then filed, as follows:

1. The original shall be filed according to the key-card number in the file of the explosives section, first in alphabetical and then in numerical order.

2. The first carbon copy shall be filed according to the test letter and number in the file of the explosives section.

As each test card passes through the computing room it shall be entered on a test record sheet, and shall be disposed of in the following manner:

1. The original copy shall go to the file of the explosives section.

2. The carbon copy shall go to the vertical file in the computing room and according to the character of test.

Before filing the test record sheets the computer shall enter in a record book known as the tabulation book the final results of the tests if such tests are within the allowable percentage of variation. If the computer finds that the tests are not within the allowable percentage of variation, no entry shall be made, and he shall notify the explosives engineer regarding the results.

The following rules apply to all test records:

1. The allowable percentage of variation is stated under "Methods of making tests." The percentage of variation is obtained by dividing the maximum difference by the average of the tests used.

2. "Degree of refinement" refers to the smallest increment to which an observation or a result is carried. If it is impossible to determine the nearest figure in the last decimal place because the remainder is exactly one-half of the increment, the nearest even figure in the last place should be used; thus, when the degree of refinement is 0.01 and the result comes exactly 0.035, 0.04 should be used.

3. Failure to get a record when such failure is due to apparatus is not counted as a trial, but is recorded and posted with proper note.

4. The office key cards are not to go to the computing room.

5. Computation tolerances are allowed in certain cases, as indicated under the particular test.

6. All weighings are considered accurate within the variation of the balance used. The plus and the minus tolerances for weighings are designed to cover the natural variations of the balance.

METHODS OF MAKING TESTS.

The methods of making the tests should be followed step by step as described below.

PHYSICAL EXAMINATION.

In making measurements of cartridges, the average figures for four cartridges set aside when the key card number was assigned should be taken.

LENGTH.

The length of cartridge is measured to the nearest one-fourth of an inch and computed to the nearest one-tenth of a centimeter.

DIAMETER.

The diameter of the cartridge is measured in the middle by a paper scale which is wrapped around the cartridge; the scale gives direct readings of the diameter of the cartridge to the nearest one-tenth of a centimeter.

The average is computed to the equivalent one-eighth of an inch, but if the equivalent is exceeded, then the next higher eighth of an inch is used.

The diameter of the explosive submitted by the manufacturer is stated.

EXPLOSIVES SUBMITTED IN BULK.

If explosives are submitted in bulk and are to be used ordinarily in newspaper wrappers, such wrappers are used in the physical examination by making the explosive into cartridges $1\frac{1}{4}$ by 8 inches.

USE OF NEWSPAPER WRAPPER.

Five grams of the newspaper is used. The paper is cut in the form of a trapezoid with sides approximately 11.5 and 16.5 inches and 10 inches wide. The length may be varied so that the paper weighs exactly 5.0 grams. The explosive is poured into the newspaper shell and jarred in order to make the cartridge compact.

KIND OF SAND USED.

The sand used in the determination of the apparent specific gravity is Lake Michigan dune sand containing only a trace of moisture and of such fineness that it will pass through a 30-mesh screen and be caught on an 80-mesh screen. The same kind of sand is used for stemming in tests with Trauzl lead blocks.

DETERMINATION OF APPARENT SPECIFIC GRAVITY.

The determination of the apparent specific gravity is made by obtaining the weight of sand displaced by a cartridge embedded in the sand. The operation consists of pouring a small quantity of sand into the bottom of a cylinder and then inserting the cartridge centrally in the cylinder with the machine-crimped end embedded in the sand. The remainder of the sand is poured into the cylinder with the spout of the sand container held as close to the cylinder as possible but without touching it; the top of the cartridge is held

centrally in the cylinder by a lead pencil. The surplus sand is smoothed off by a straight edge. The sizes of cylindrical sand container to be used with the various diameters of cartridges are as follows:

Sizes of cylindrical sand containers to be used in determinations of apparent specific gravity.

Nominal diameter of cartridge, inches.	Inside diameter of cylinder, inches.
Up to 1	1⅜
More than 1 to 1⅜	1¾
More than 1⅜ to 1¾	2¼
More than 1¾ to 2	2⅝

WEIGHING.

Weights, expressed to the nearest gram, are recorded as follows: 1. Each cartridge. 2. Average of the four cartridges. 3. Cylinder filled with sand. 4. Cylinder containing a cartridge and filled with sand. 5. Sand displaced by cartridge—equal to item 1 plus item 3 minus item 4.

VOLUME OF CARTRIDGE.

The volume of cartridge by sand is taken as the weight of the sand displaced by the cartridge divided by the specific gravity of the sand. The volume and the average volume are expressed to the nearest cubic centimeter (see Table 1, p. 44).

The apparent specific gravity of a cartridge by sand equals the average weight divided by the average volume; the result is expressed to the nearest one-hundredth.

GENERAL EXAMINATION OF CARTRIDGE.

After the aforementioned determinations have been made, the following data should be recorded:

1. Whether cartridge has been redipped.
2. Whether cartridge is spirally wrapped.
3. Hardness of cartridge as a whole, statement being made as to whether it is (*a*) very hard; (*b*) hard; (*c*) soft; or (*d*) very soft.

Whether a cartridge has been redipped can usually be determined by carefully opening the wrapper. If there is a greater thickness of paraffin near the edge where the sheet overlaps, or if the overlapping edge is attached to the adjacent parts of the paper by an adhering deposit of paraffin, it may be assumed that the cartridge has been redipped.

REMOVAL OF EXPLOSIVE FROM WRAPPER.

After making all the above determinations, explosive ingredients should be removed from the wrapper. Care should be taken so that none of the explosive adheres to the wrapper; also that none of the paraffin is lost.

WEIGHT OF WRAPPER.

The wrapper of each cartridge, including the paraffin coating, should be weighed to the nearest one-tenth of a gram. The weight of explosive is the difference between the weight of the cartridge and that of the wrapper.

WEIGHT OF WRAPPER PER 100 GRAMS.

The weight of wrapper per 100 grams of explosive is expressed to the nearest one-tenth of a gram, and is computed by multiplying the weight of wrapper by 100 and dividing by the weight of the explosive. An average is computed and expressed to the nearest one-tenth of a a gram and recorded on the second page of the test cards.

WEIGHT OF WRAPPER USED IN PHYSICAL TESTS.

The weight of wrapper used in all physical tests for a given diameter of cartridge is expressed to the nearest 0.5 gram and is recorded on the first page of the test cards with data on the physical examination.

COLOR.

The following observations can next be made:

The color of both the explosive and wrapper should be stated in one of the forty-eight colors illustrated in the Standard Dictionary under the word "spectrum."

CONSISTENCE.

The consistence of the explosive itself should be classified in reference to the following data:

1. Granulation:
   - (*a*) Structure—
     - Granular (if structure is entirely granular).
     - Granular, fibrous (signifying that the quantity of granular particles is equal approximately to the quantity of fibrous particles).
     - Granular, slightly fibrous (signifying that the explosive is composed of more granular than fibrous particles).
     - Fibrous, slightly granular (signifying that the explosive is composed of more fibrous than granular particles).
     - Fibrous (signifying that all particles are fibrous).
     - Pulverulent.
     - Gelatinous.
   - (*b*) Size—
     - Very fine.
     - Fine.
     - Coarse.
     - Very coarse.

2. Liquidness:
   Very wet.
   Wet.
   Dry.
   Very dry.

3. Compactness of the cartridge as a whole, or if the explosive be composed of granules in pellet form, then the state of compactness refers to these granules. State also whether the granules are brittle or plastic; very hard; hard; soft; or very soft.

4. Cohesiveness:
   Very cohesive.
   Moderately cohesive.
   Slightly cohesive.
   Not cohesive.

GENERAL DATA.

The markings on the cartridge should be stated on the test cards.

The data pertaining to the physical examination should be entered in the "data tabulation book" as for the manufacturer's nominal diameter[a] of 1¼ inches.

TOLERANCES FOR FIELD SAMPLES AND OTHER SAMPLES OF SAME DIAMETER OF CARTRIDGE.

1. The tolerance for the weight of wrapper per 100 grams of explosive is ±2.0 grams (average of four determinations).

2. The tolerance for the apparent specific gravity of cartridge by sand is ±7.5 per cent (average of four determinations).

3. The samples submitted by the manufacturer for the determination of 1 and 2 are to be considered standard for these items.

TESTS WITH BALLISTIC PENDULUM.

PERMISSIBILITY TESTS.

The object of the test with the ballistic pendulum is the determination of the unit deflective charge of an explosive. The procedure in different kinds of shots is as follows:

SHOT WITH BLACK BLASTING POWDER.

In order to loosen the pendulum, a charge of 375 ±0.5 grams of FFF black blasting powder is used in loading the cannon, as per method (see p. 20), and fired by an electric igniter. A record of the test is made in the usual way.

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[a] It has been found that the outside diameter of a cartridge is usually slightly in excess of that claimed by the manuafcturer; hence the diameter claimed by the manufacturer is considered the "nominal" diameter.

SHOT WITH STANDARD DYNAMITE.

Three trials, agreeing within 5 per cent, are made, with 227 ±0.5 grams of the Pittsburgh experiment station standard 40 per cent "straight" nitroglycerin dynamite. Each charge is fired by a No. 6 electric detonator. The swing of the pendulum is noted for each, and the computed average is known as the "unit swing" and is determined for each date upon which tests are made.

SHOTS WITH EXPLOSIVE UNDER TEST.

Tentative trials, with varying weights of the original $1\frac{1}{4}$-inch by 8-inch cartridges are made until the swings in three of the trials in which the same weight of the explosive has been used agreed within 5 per cent, and the average swing agrees within 0.20 inch of the unit swing. All charges should be weighed and reported to the nearest gram and should not vary from the stated quantity more than 0.5 gram.

UNIT DEFLECTIVE CHARGE.

The unit deflective charge is calculated by the following proportion: Average swing: unit swing:: weight of charge: (the unit deflective charge).

ELECTRIC DETONATOR.

The grade of electric detonator used should be that recommended by the manufacturer for use with the explosive, but can not be less than a No. 6; however, an electric igniter may be used with a slow-burning explosives.

GENERAL RULES FOR PERMISSIBILITY TESTS.

General rules applying to all tests of explosives for permissibility follow:

1. Trammel the knife edges.
2. The face of the cannon jacket must be parallel to the face of the mortar and one-sixteenth of an inch from it.
3. State to the nearest inch the distance the cannon is thrown back.
4. The observations and computed results from the recording device should be expressed to the nearest 0.01 inch.
5. Careful observation should be made to see that detonation is complete, and indications of incomplete detonation should be brought to the attention of the assistant engineer.

Tests requirements for permissible explosives.

The unit deflective charge should not exceed 454 grams (1 pound).

The explosive is considered unsatisafctory if two or more charges fail to detonate or explode completely.

SUITABILITY TESTS.

Suitability tests are made in a manner similar to those for permissibility, with the following exceptions:

UNIT SWING.

The unit swing is the average of two trials agreeing within 5 per cent with 227 ±0.5 grams of the Pittsburgh experiment station standard 40 per cent "straight" nitroglycerin dynamite.

NUMBER OF TRIALS.

The results of trials of the explosive under test that agree within 5 per cent are taken, and their average must be within 0.20 inch of the unit swing. The explosive tested is to be detonated by an electric detonator, as recommended by the manufacturer—No. 6 or higher. Electric igniters may be used with slow-burning explosives.

FORMULA FOR PITTSBURGH EXPERIMENT STATION STANDARD 40 PER CENT "STRAIGHT" NITROGLYCERIN DYNAMITE.

The formula for this dynamite is as follows:

Nitroglycerin	40
Sodium nitrate	44
Wood pulp	15
Calcium carbonate	1
	100

TOLERANCE FOR FIELD SAMPLES AND OTHER SAMPLES OF PERMISSIBLE EXPLOSIVES.

The tolerance for the unit deflective charge (the average of three trials with the ballistic pendulum) for such samples shall be ±10 per cent.

PLASTIC MILLED FIRE CLAY FOR STEMMING.

Plastic milled fire clay is used for stemming in the cannons used at the ballistic pendulum and at gas-and-dust gallery No. 1. The fire clay is dried to 0.42 per cent of moisture or less and ground to 20-mesh fineness.

SIZE OF CANNON.

A new cannon used in ballistic-pendulum tests shall contain a liner having a diameter of 9½ inches. The diameter of the bore hole shall be 2¼ inches and the length 21½ inches. The cannon and liner are assigned the same serial number, which is recorded in the cannon notebook. When the bore hole is enlarged to the degree mentioned below, if neither the cannon nor the liner is cracked,

the liner is drilled for a liner of 5-inch diameter with a $2\frac{1}{4}$-inch bore hole. This liner is given the next serial number. In the past there have been instances in which $5\frac{1}{2}$, 6, $6\frac{1}{2}$, and 7 inch liners have been used in succession.

A plug of asbestos rope must be rammed tightly into the far end of a new bore hole. It should occupy about 1 inch along the bore hole. The explosives fired in the bore hole chamber the hole, and when the chambered part of the hole is more than $2\frac{3}{4}$ inches in diameter, as measured by calipers in a vertical position, the chambered part of the bore hole is filled with fire clay, and another plug of asbestos rope is introduced between the fire clay and the explosive in making test 4 at the gallery; for ballistic-pendulum tests and tests 1 and 3 at the gallery the diameter of the chambered part must not exceed 3 inches.

A bore hole is of no further use for test 4 when the last clear part of the bore hole is less than 1 inch. It is, however, suitable for making ballistic pendulum tests and tests 1 and 3 at the gallery. For the latter tests the last clear portion of the bore hole should not usually be less than 2 inches.

The temperature of the bore hole should be stated on the test card and may vary from 13° to 30° C.

METHODS OF CHARGING CANNON.

A. Method A of charging the cannon is used in test 4 when explosives containing nitroglycerin are charged. The charging is done in two ways as described below.

CHARGING DENSITY OF 1.

A primer 2 inches long is cut from one of the cartridges in which is inserted centrally the electric detonator. The remaining cartridge or cartridges are cut on both sides and across each end and tamped firmly into the bore hole. No additional pressure is exerted after the charge completely fills the bore hole. The primer is gently pressed against the charge.

CHARGING AIR-SPACED.

An explosive is charged air-spaced in making test 4 only when the unit deflective charge is less than 300 grams and the rate of detonation is more than 3,000 meters per second. The cartridges are not cut. The electric detonator is inserted centrally in one of the cartridges. The cartridges are flattened slightly and introduced into the bore hole in pairs and pressed to the back of the bore hole. The cartridge containing the electric detonator is made one of the last pair placed.

B. Method B is used in test 4 for charging all ammonium nitrate explosives that contain no nitroglycerin. The method of charging for a density of 1 is the same as that described as method B, except that the cartridges are rolled until soft before being charged, and the tamping is done gently instead of firmly, and except that in air-spaced charging the cartridges are rolled until soft before being charged.

C. Method C is used in the ballistic pendulum and all gallery tests for charging black blasting powder and similar explosives. The entire charge is tamped firmly and then the electric igniter is inserted directly in the charge. If stemming is used, 2 pounds is put in, 1 pound at a time, and pressed home firmly. The last pound is tamped very hard.

D. Method D is used in ballistic-pendulum tests and in gallery tests 1 and 3 for charging explosives containing nitroglycerin, and with which stemming is used. The 2-inch primer is first inserted in the bore hole with the electric detonator pointing outward, and the split cartridges are tamped firmly in front and around it.

E. Method E is used in ballistic-pendulum tests and in gallery tests 1 and 3 for charging all ammonium nitrate explosives that contain no nitroglycerin, and with which stemming is used. The cartridges are rolled until soft before charging, and the stemming is put in gently instead of firmly, otherwise the procedure is the same as for method D.

CANNON RECORDS ON TEST CARDS.

In all tests in which a cannon is used entries regarding the following details should be made on the test cards:

The number of the cannon and liner used should always be stated and the distance the liner extends out should always be given to the nearest one-sixteenth of an inch.

The method of charging should be stated. The diameter and the clear parts of the bore hole are given to the nearest one-sixteenth of an inch.

The recoil is stated to the nearest one-quarter of an inch.

When a cannon is changed the condition of the old cannon should be stated on the test cards.

TESTS IN GAS-AND-DUST GALLERY NO. 1.

Gas-and-dust gallery No. 1 is used for ascertaining the effects of explosives when fired in or into explosive or inflammable mixtures.

USE OF NATURAL GAS IN TESTS.

In all tests in which natural gas is used, the allowable limit of variation is 0.25 per cent above or below the stated percentage.

unless the analysis indicates a more sensitive mixture and there is no ignition. If the analysis indicates a less sensitive mixture and there is an ignition, that test will be considered as within the limit of variation.

TIME INTERVALS FOR ADMITTING GAS.

When gas is admitted into the first division of the gallery, the following time intervals must be followed:

Running in gas—3 minutes for test 1, and 2 minutes for test 2 (new) and test 4.

Mixing gas and air—6 minutes for test 1, and 5 minutes for test 2 (new) and test 4.

Starting sampling to turning off fan—1½ minutes.

Turning off fan to firing shot—1 minute.

SAMPLES OF GAS-AIR MIXTURES.

A sample of the gas-air mixture is taken in every test in which natural gas is used and the percentage of methane plus ethane determined.

The bureau section charged with the investigation of gases, on the 1st and 16th days of each month, makes a complete analysis of a sample of the natural gas.

The gas-air mixture is confined in the first division (20 feet) of the gallery by a large paper diaphragm.

USE OF COAL DUST IN TESTS.

The coal dust is obtained by grinding 60 pounds of broken lump coal for 3½ hours in a cylindrical cast-iron pebble mill. The coal used is procured from the Pittsburgh bed at the experimental mine of the Bureau of Mines.

For test 3, 40 pounds of the coal dust is used. Twenty pounds is distributed uniformly on a horse placed in front of the cannon and 20 pounds is placed on side shelves in sections 4, 5, and 6 (the second 20 feet) of the gallery.

For test 2 (new) and test 4, 20 pounds of the coal dust is used. Eighteen pounds is placed on lateral shelves along the first 20 feet of the gallery, and 2 pounds is placed near the inlet of the mixing system in such a manner that all or part of the dust will be suspended in the first division (20 feet).

VARIATION IN THE TEMPERATURE OF THE GALLERY.

The variation of gallery temperature during tests may be 20° to 30° C.

RECORDS MADE FOR ALL TRIALS.

The result of a trial is recorded as "Ignition" or "No ignition"; and in addition when coal dust is used, an entry, "Dust charred" or "Dust not charred," is made.

OBSERVATIONS REGARDING FLAMES.

The flame observations made are as follows:
The number of doorways through which flame issues.
The number of windows through which flame is seen.

OBSERVATIONS REGARDING DOORS.

Record the number of doors that opened and closed, opened and stayed open, or remained closed. All doors are closed but left unfastened in test 3, but in all other tests the first three doors are left open, the doorways being closed by small paper diaphragms. Doors are said to open and close when they fall back on the gallery and rebound.

OFFICIAL GALLERY TESTS.

The official gallery tests are tests 1, 3, and 4. An ignition concludes all tests.

TEST 1.

The number of tests required is 10 "no ignitions." The weight of charge is the unit deflective charge ± 0.5 gram, loaded in cannon as per methods C, D, or E, with 1 pound of dry fire-clay stemming. The percentage of methane and ethane used is 8.00 ± 0.25.

TEST 3.

The number of tests required is 10 "no ignitions." The weight of charge is the unit deflective charge ± 0.5 gram, loaded in cannon as per methods C, D, or E, with 1 pound of dry fire-clay stemming. Coal dust only is used in the gallery.

TEST 4.

The number of tests required is five "no ignitions."

Charging air-spaced.—The weight of charge is 680 ± 1 gram, loaded in cannon as per methods A or B, air-spaced. The percentage of methane and ethane is 4.00 ± 0.25. Coal dust is used on the shelves.

Charging with density of 1.—If the explosive when loaded in the cannon air-spaced causes an ignition, such test is then considered unofficial and further charging air-spaced on this test is discontinued. The explosive is now charged with a density of 1, the number of tests required being five "no ignitions."

COMPLETE OR INCOMPLETE DETONATION.

The explosive is considered unsatisfactory if in the gallery tests two or more charges fail to detonate or explode completely. The testing engineer should therefore make careful observations to ascertain whether detonation is complete, and any indications of incomplete detonation should be brought to the attention of the assistant engineer.

SIZE OF CARTRIDGE USED.

Usually and whenever practicable, 1¼-inch cartridges should be used in all gallery tests. The weight of the charge, as entered, should include both the explosive and the wrapper.

GRADE OF ELECTRIC DETONATOR USED.

The grade of electric detonator used is a No. 6 or stronger, as recommended by the manufacturer. With slow-burning explosives an electric igniter may be used.

HANDLING OF MISFIRES.

See "Handling misfires," on page 7.

TOLERANCES FOR FIELD SAMPLES OF PERMISSIBLE EXPLOSIVES.

In the retesting of permissible explosives by tests 1, 3, and 4 the charges of the explosives fired will be reduced 10 per cent in weight from the weights originally used.

UNOFFICIAL GALLERY TESTS.

TEST 2 (NEW).

An explosive, to become permissible, is not required to pass this test. The number of tests required is three "no ignitions" with the explosive, in its original wrapper, suspended in the central part of the first division of the gallery. Gallery conditions are like those for test 4. The quantity of explosive used is 454 ± 1 gram. When an ignition is obtained further trials are made with the explosive repacked in parchment paper wrapped straight. The number of such tests required is three "no ignitions."

KIND OF WRAPPER.

The kind of wrapper used for the explosive in all trials should be stated both on the test cards and on the test-record sheets.

The thickness of the paper may vary in different purchases. In order that the same weight of paper may be used in each test the paper should be cut so that the length of shell, uncrimped, is 10.5 inches, and the other dimension of the sheet at right angles is such that the total weight of one sheet is 2.2 grams. This dimension may be determined for each shipment so that it will not be necessary to test each sheet for weight.

TESTS IN SMALL GAS AND DUST GALLERY NO. 1.

No standard tests have been established for this piece of apparatus. Tests made there have been entirely experimental.

RATE OF DETONATION BY METTEGANG RECORDER.

The time required for the detonation of a meter length of explosive is determined. The rate of detonation, in meters per second, is then computed.

CALIBRATION OF SPARK POINTS OF METTEGANG RECORDER.

The calibration should usually be made before each series of tests.

Determine the component of the actual distance between the platinum-tipped spark points, in the direction of the rotation of the drum, by lowering the arm holding the points until they just scratch the soot on the bronze drum while the arm is moved a short horizontal distance by means of the micrometer screw. Then measure the distance between the lines by the micrometer measuring device.

The results of these calibrations are written under the key number of the Mettegang recorder (M-437), which is used for the numerator, and recorded as a miscellaneous test. The number of the calibration test that applies should be stated on each rate-of-detonation test.

PERMISSIBILITY TESTS.

The explosive, in its original wrapper, with the ends of the cartridge cut off is inserted in a tube, care being taken to make a continuous file of explosive. The tube is made from one piece of 28-gage galvanized sheet iron with a straight soldered lap joint or an interlocking joint. The inside diameter of the tube should be stated, and must be one-eighth of an inch greater than the nominal diameter of the cartridge used. The length of the tube is 42 inches. Four holes are drilled transversely and centrally through the tube; the first hole is 2 inches from the end of the tube in which the detonator is inserted. The first and second and the second and third holes are one-quarter meter apart, and the third and fourth holes are one-half meter apart, measurements being made center to center. Each hole has a diameter of 0.120 inch, being made by a No. 31 drill. After the explosive has been inserted in the tube, insulated copper wires, B. & S. gage No. 22, are inserted through the holes and the explosive. A pointed piece of copper wire, B. & S. gage No. 13, (0.07196 inch in diameter) is used for making the holes through the explosive.

The explosive is always fired in a cartridge having the smallest diameter in which the manufacturer wishes to market his explosive, and also in a cartridge 1¼ inches in diameter. These trials are made in triplicate within 5 per cent. When the explosive fails to detonate completely in any trial, the test is discontinued for cartridges of that particular diameter or smaller.

The record of each test should show whether the cartridge is used as received or whether the explosive has been repacked; the weight of the explosive to the nearest gram; and the calibration test number.

The peripheral speed of the drum is usually 45 meters per second, corresponding to an angular velocity of the drum of 90 revolutions per second, and the circumference of drum is 500 millimeters.

The rate of detonation is obtained by dividing the peripheral speed of the drum by the distance between the spark points (see Table 2, p. 45).

The electric detonator used is the No. 7, which is completely inserted centrally in the end of the cartridge file.

The distance between spark points is 0.1 millimeter; the rate of detonation, for a single test, is 1 meter (3.28 feet) per second, and the average rate of detonation is 1 meter per second and 10 feet per second.

Separate test record sheets are made for each diameter of cartridge but only the rate of detonation of a $1\frac{1}{4}$ inch cartridge (manufacturer's nominal diameter) shall be entered in the data tabulation book.

SUITABILITY TESTS.

Suitability tests are made in a similar manner to those for permissibility, with the following exceptions:

Trials are made until duplicate trials agree within 5 per cent.

An electric detonator is used; usually a No. 6 electric detonator is used; none of less strength is ever used. A higher grade detonator may be used if recommended for use with the explosive; or electric igniters may be used with slow-burning explosives.

TOLERANCE FOR PERMISSIBLE EXPLOSIVES.

The tolerance for the rate of detonation (the average of three trials with Mettegang's recorder) is ± 15 per cent.

RATE OF DETONATION BY DETONATING FUSE (CORDEAU DETONANT).

For the rate of detonation test, a cartridge of explosive or an explosive file is suspended in the air; within the cartridge or file, at a known distance apart are placed two detonators, into each of which is previously crimped one end of a continuous detonating fuse, usually about 1 yard long. This fuse is bent so as to lie on a lead plate $\frac{1}{2}$ inch by 3 inches by 15 inches in such a way that its middle point is directly over a previously marked position on the plate.

After the cartridge has been fired, by an electric detonator inserted centrally in the cartridge, the distance between the mark on the lead plate and the point on the lead plate at which the detonations meet is measured.

The rate of detonation is determined by the formula: $x=\frac{ac}{2b}$

in which, x = rate of detonation of explosive; a = rate of detonation of fuse; c = distance apart of ends of fuse in explosive file; b = distance on lead plate between center of fuse and mark.

x and a and c and b should be in the same units; that is, if a, the rate of detonation of the fuse is expressed in meters per second, then x will be in meters per second, even though c and b are both expressed in inches or some other unit.

FLAME TEST.

The flame-test apparatus is used to record, by photography, the relative lengths and durations of the flames of explosives under the conditions of the test. The weight of charge of explosive, including the wrapper, is 100 ± 0.5 grams, $1\frac{1}{4}$-inch cartridges being used.

The charge is divided into equal parts by cutting it transversely through the middle. The wrapper of both parts is slit along the sides. One part is placed in the bore hole and pressed gently with a special tamping device. The legs of the electric detonator used are bent near the end of the electric detonator at right angles to it, and the electric detonator is lowered so that it rests flatly on top of the first part of the charge. The remainder of the charge is placed in the bore hole and pressed in place gently but firmly by a special tamping device consisting of two wooden rods joined by a hinge. The diameter of the rods is slightly less than the diameter of the bore hole. The lower part of the device is about 9 inches longer than the depth of the bore hole.

The upper part of the device, which is about 3 feet long, is held in a horizontal position and is used to actuate the lower part in such a way that no part of the body of the operator is near the axis of the bore hole.

No other tamping device is allowed to be used.

The temperature of the cannon should be about room temperature.

The outside temperature should be stated on the record, as well as the time of firing the shots and the length of the clear part of the bore hole before and after the charge is in place.

The prescribed peripheral speed for explosives of short duration of flame is 20 meters per second, and for explosives of long duration $\frac{20}{64}$ meter per second. The circumference of the film is 500 millimeters. The angular velocity is usually 40 revolutions per second.

Three photographs of the same explosive are made on a single film. Extra tests are to be made if the pictures overlap. The film is sent to the photographer in a light-tight tin can sealed with adhesive tape.

The testing engineer makes out duplicate receipt cards 4 by 6 inches, giving in the index fraction the key number of the explosive and the flame-test numbers. One copy of the receipt is for the explosives section and the other for the technical-service section, which does the developing.

After the filing of the record sheet the assistant engineer makes a work requisition (on Form 6–1) for seven prints from the negatives of the flames that have been measured and have indicated satisfactory explosions.

The height of the flame shown on the photograph is measured on a vertical line from the level of the bottom of the flame to the extreme top.

The duration distance is measured on a horizontal line from extreme point to the center of the base of the flame.

The height of the flame in inches is obtained by multiplying its height in the photograph in millimeters by $12/9.5 = 1.2632$ (see Table 3).

The duration of the flame in milliseconds is obtained by multiplying the duration distance in millimeters by the reciprocal of the speed (meters per second) of the drum.

The electric detonator or electric igniter used is of the same grade as that used in the gallery tests.

The degrees of refinement must be as follows:

Height of photograph to the nearest 0.25 millimeter;

Height of flame (single test) to the nearest 0.01 inch;

Height of flame (average) to the nearest 0.01 inch;

Duration distance to the nearest 0.25 millimeter;

Duration of flame (single test) to the nearest 0.001 millisecond;

Duration of flame (average) to the nearest 0.001 millisecond.

If a photograph shows a flame is less than 5 millimeters high, notify the explosives engineer before averaging; otherwise average regardless of variation.

SMALL IMPACT TEST.

The small impact machine is used in the determination of the relative sensitiveness of explosives to explosion, as indicated by the blow of a known mass of steel dropped from varying heights.

In each trial the charge of explosive used is 0.02 gram, to be taken from the middle of an original cartridge. After the charge has been weighed on a chemical balance, the charge is wrapped in tinfoil and placed in a desiccator (containing no desiccating material).

The charge as used is transferred from the tinfoil onto an anvil and spread out in the form of a flat disk having a diameter of 1 centimeter.

The lower face of the plunger has a diameter of 1 centimeter. Previous to a trial the plunger is lowered and gently pressed upon the explosive. Trials are made by dropping the weight from known elevations.

The following records are required:

The weight of the plunger to the nearest gram, which must weigh 900 ± 25 grams. The weight used is 2,0005 $\pm$grams.

The temperature of the room should always be given to the nearest degree centigrade, and the water circulating through the anvil should always be at $25° \pm 2°$ C.

The height of the fall given to the nearest centimeter.

The result of every trial should be either: No explosion, slight explosion, or sharp explosion.

The trials when recorded on the test record sheets should be given in the same order as on the test cards, which is the order in which they are made.

The number of trials required is at least six.

The maximum height is established by five "no explosion" trials at a height 1 centimeter below a point at which at least a slight explosion is obtained.

Degree of refinement, 1 centimeter (0.3937 inch) and 0.01 inch.

EXPLOSION-BY-INFLUENCE TEST.

The explosion-by-influence test determines the sensibility of an explosive to the explosion wave produced by the detonation of an equal mass of the same explosive and transmitted through the air.

The size of the cartridges used is always $1\frac{1}{4}$ by 8 inches. If the cartridges are repacked, statement to that effect should be made on the test card. The density of the charges should correspond to the apparent specific gravity of a cartridge $1\frac{1}{4}$ by 8 inches, as determined by sand.

The weight of each cartridge must be 160.88 multiplied by the apparent specific gravity and expressed to the nearest gram. Use essary quantity of explosive from one end, or, if the cartridge is Table 4. If the original cartridge weighs too much, remove the nec- under weight, add the necessary quantity.

The two cartridges are suspended vertically end to end, with a clear space between them and with their axial lines coincident.

The clear space between cartridges is always a multiple of 1 inch.

State the time of firing the shot. The result of the second cartridge should always be stated, as "Exploded," or "Did not explode."

If a cartridge does not explode, the length of cartridge remaining suspended should be stated.

The second cartridge is not considered as having exploded as long as any part of it can be found.

The grade of electric detonator used is that recommended by the manufacturer. The electric detonator is entirely embedded centrally in the lower end of the lower cartridge.

The number of tests required is at least four, the minimum distance at which no explosion occurs being determined by three shots in which the cartridges are separated a distance 1 inch greater than a distance at which the second cartridge explodes. This test is usually made only on explosives submitted to determine their permissibility.

TESTS TO DETERMINE PRESSURE IN OWN VOLUME.

The Bichel pressure gages determine pressures from which can be computed the theoretical maximum pressure of an explosive when fired in its own volume.

For permissible explosives that detonate, the charge is 200 $\pm$0.5 grams of explosive plus the proportionate amount of original wrapper, as indicated in the physical examination for a cartridge 1¼ inches in diameter. After the wrapper has been removed from the explosive, the ends should be cut away. If the ends are discolored, the entire discolored parts should be cut away and discarded.

The charge is usually fired with a diameter of cartridge of 1¼ inches, although it may be found necessary to increase this diameter in order to insure complete detonation.

The diameter and length of cartridge is measured to the nearest one-tenth of a centimeter. The density of the charge should correspond to the apparent specific gravity, as shown in the physical examination.

The pressure bomb should be wiped out as dry as possible before each shot.

The electric detonator used is a No. 7; with a slow-burning explosive an electric igniter may be used. If the latter is used, experience with gage tests for the gaseous products will have shown the best method of firing; usually the gage must be full of air at atmospheric pressure, but otherwise a vacuum should be obtained. The vacuum must be 50 $\pm$5 millimeters, which is the difference between the barometer and manometer readings. The temperature of the gage should be given to the nearest degree centigrade, and the time of firing should be stated. It is desirable to use a spring that gives a curve 35 $\pm$ 10 millimeters high. The assistant engineer, when issuing orders for gage tests, should recommend the spring with which to start on the first trial, and the same spring should usually be used for all trials with the same explosive, except when the first trial indicates the desirability of a change.

PROJECTION OF COOLING LINE FOR PERMISSIBLE AND HIGH EXPLOSIVES.

The projection of the cooling line should be drawn through two points. The first point should be taken at approximately one-third

the length of the card from the initial vertical line unless there is evidence that the piston stuck at that point or that the vibration of the moving parts has not ceased. The second point for projection of the cooling line should be taken at the opposite end of the card and on the first line or the corrected position of that line if evidence is sufficient to absolutely establish that corrected position.

MEASUREMENT OF PRESSURE IN TESTS OF LOW EXPLOSIVES.

As regards low explosives, like black blasting powder, the charge used is usually 300 grams plus 2.5 grams of newspaper wrapper per 100 grams of explosive. The measurement of pressure from the indicator cards is as follows:

The maximum pressure is usually reached in about one revolution of the drum and continues constant for approximately another revolution.

The number of revolutions and fraction thereof from the firing of the shot is measured off on the card to the point where the pressure begins to fall, owing to the cooling of the gases. At this latter point the maximum pressure is scaled off and to this is added the average fall in pressure through three succeeding revolutions. This sum gives the corrected normal pressure.

MEASURING HEIGHT OF CURVE.

The height of curve should be scaled to the nearest 0.25 millimeter.

The pressures developed in the gage are computed to the nearest 0.01 kilogram per square centimeter by dividing the height of the curve in millimeters by the value for the particular spring used. Each value is expressed to the nearest 0.01 millimeter as being equivalent to 1 kilogram per square centimeter. There are four springs in use. The markings on these and the values to be used for division are stated below and should be recorded on test cards:

For the spring marked 15 millimeters 4 kilograms, divide by 0.60 millimeter = 1 kilogram per square centimeter.

For the spring marked 10 millimeters 6 kilograms, divide by 0.40 millimeter = 1 kilogram per square centimeter.

For the spring marked 8 millimeters 8 kilograms, divide by 0.32 millimeter = 1 kilogram per square centimeter.

For the spring marked 6 millimeters 10 kilograms, divide by 0.24 millimeter = 1 kilogram per square centimeter.

Use Table 5 (p. 49) for making the computations.

COOLING SURFACES.

The cooling surface of pressure bomb No. 1 is 3,914 square centimeters.

The cooling surfaces of pressure bomb No. 2 are varied by means of blocks; when the largest block is used, the cooling surface is 6,555

square centimeters; when the three smaller blocks are used, the cooling surface is 7,624 square centimeters.

REQUIRED NUMBER OF TESTS IN TESTS FOR PERMISSIBILITY.

The required number of tests for each of the three cooling surfaces is three, with an allowable variation of 5 per cent.

COMPUTATION OF PRESSURE IN OWN VOLUME.

The pressure for no cooling surface is obtained from the formula $P=1.911A+0.5B-1.411C=$number of kilograms per square centimeter expressed to the nearest 0.01 with a tolerance of ± 0.03, in which A, B, and C are pressures for the cooling surfaces 3914, 6555, and 7624. The pressure in own volume (M) is obtained from the formula $M=\frac{VPS}{W}$, in which S is the apparent specific gravity; P the pressure for zero cooling surface; V = 15,000 cubic centimeters, and W = weight of charge that includes the wrapper; M is expressed to the nearest kilogram per square centimeter with a computation tolerance of ± 1.0 and to the nearest 10 pounds per square inch.

Pounds per square inch $= 14.2232 \times$ kilograms per square centimeter. (Previous to March 23, 1912, the factor used was 14.2242)

CARE OF PISTON AND CYLINDERS OF INDICATOR MECHANISM AND OF OTHER PARTS.

The number of both the piston and the cylinder used in the test should be stated.

The piston operates best (sticks least) when the end of the hole in the cylinder is well covered with a thick mass of vaseline. All parts of the pi ton and the cylinder should be thoroughly cleaned immediately after use The solid products of combustion soon harden and become difficult to remove.

The vacuum pump operates best when heavy oil is used in moderation. The oil should just show in the indicating glass when the pump is working.

After creating a vacuum in either gage and before shutting down the pump, close the gage and release the vacuum in the piping system. This will prevent the oil in the pump from being sucked into the pipes.

Release the gaseous products of combustion directly into the exhaust pipe. Do not pass them through the pump.

SUITABILITY TESTS.

The suitability tests are made like the permissibility tests, with the following exceptions:

The tests with each cooling surface are made in duplicate within 5 per cent.

The electric detonator used is of the grade recommended by the manufacturer and is usually a No. 6; with slow-burning explosives an electric igniter is used.

LARGE IMPACT TEST IN PERMISSIBILITY AND SUITABILITY TESTS.

The large impact machine is similar to the small impact machine, but gives results on a larger scale.

Both confined and unconfined charges are prepared. The weight of explosive used is 20 ± 0.5 grams. The ends and the discolored parts of the explosive from which charges are taken are cut away and discarded. The charges are prepared and maintained at room temperature until just before testing. The explosive is spread in the form of a flat disk of uniform thickness and having a diameter of 10 centimeters. With the confined charges, the explosive is placed between two steel disks, each three-eighths of an inch thick. The two disks are of such a diameter that they will fit easily into a section of Shelby steel tubing lined with one thickness of paper. The Shelby tubing is made of cold-drawn seamless steel and has an outside diameter of $4\frac{1}{4}$ inches, an inside diameter of 3.858 inches, and a thickness of 0 196 inch. It is cut in the lathe in sections twenty-thirty-seconds of an inch high. The edges are parallel and cut square.

With the unconfined charges the explosive is placed between two steel disks, each 0.75 inches thick, and with a diameter of 5 inches. The disks with the explosive charge between them are placed on the anvil, and the plunger is carefully lowered Trials are made by dropping the weight from known elevations. The weight used is 200 kilograms.

The record should show the temperature of the disks and the outside temperature to the nearest degree centigrade and whether the charge is confined or unconfined.

The height of the fall above 10 centimeters should vary by 10 centimeters, and below 10 centimeters trials may be made at 5 and 2.5 centimeters.

The result of every trial should be recorded as "No explosion," "partial explosion," or "complete explosion."

As regards partial explosions in which the charge is unconfined, the quantity of explosive recovered should be estimated to the nearest gram.

Should the explosion be not complete in any trial in the course of testing to establish the maximum height of no explosion, drops should

be made with increasing heights varying by 100 centimeters until complete explosion is obtained.

When the fall is above 10 centimeters, the maximum height of no explosion is established by three "no explosion" trials within 10 centimeters when an explosion occurs at 10 centimeters higher. However, should the explosion occur when the fall is 10 centimeters, trials should be made with a fall of 5 centimeters, and if then an explosion occurs make three trials with a fall of 2.5 centimeters.

Degree of refinement, 0.5 centimeter and 0.01 inch.

One centimeter = 1/2.54 = 0.3937 inch.

REMOVING DISKS FROM RING.

A hardwood mandrel and hardwood disk are used under the plunger of the large impact machine for removing the disks from the ring when they are not too tightly wedged therein.

Great care should be exercised in handling unexploded unconfined charges and especially when the explosive is between confined disks.

HEAT DETERMINATIONS IN PERMISSIBILITY TESTS.

The heat liberated by the detonation of a known weight of explosive is determined in the calorimeter.

For permissible explosives that detonate, the charge is 100 ± 0.5 grams of explosive plus the proportionate amount of original wrapper as indicated in the physical examination for cartridges $1\frac{1}{4}$ inches in diameter. Cut away and discard the ends and discolored parts of the original cartridge from which the sample is taken.

The charge is usually fired within a cartridge having a diameter of $1\frac{1}{4}$ inches, although it may be necessary to increase this diameter (but with no change in the amount of paper wrapper) in order to insure complete detonation.

The diameter and length of charge is measured to the nearest 0.1 centimeter, and the volume is computed to the nearest 0.1 cubic centimeter.

The electric detonator used is a No. 7; or an electric igniter is used with a slow-burning explosive.

The vacuum must be 50 ± 5 millimeters, which is the difference between the barometer and the manometer readings. However, the charge of some explosives has to be fired in air at atmospheric pressure in order to procure complete explosion. The temperature of the room should be read to the nearest degree centigrade.

The weight of the calorimeter with water, the weight of the calorimeter without water, the weight of water, the water equivalent of the calorimeter, and the total equivalent of water are either observed or computed to the nearest 0.05 kilogram. The thermometer reading is taken every two minutes until the charge is exploded, after

which the thermometer is read every five minutes. The thermometer is read to the nearest 0.001° C., and the rate of cooling or heating is indicated by the difference in temperature.

The average rate of cooling or heating in calorimeter tests shall be taken to cover the period subsequent to the ignition of the charges, beginning with that observation where the rate of change begins to be reasonably constant. The correction for this rate of cooling or heating is obtained by multiplying the average by the time elapsing between time of ignition and the time when the cooling or heating begins to be constant. This product is subtracted from the total rise in temperature if the calorimeter absorbs heat from the exterior, and is added if the calorimeter radiates heat to the exterior. This method gives the rise in temperature, which is multiplied by the figure for the total equivalent water and from this is subtracted the heat of one No. 7 electric detonator, namely, 0.86 calorie. The final result is then computed and expressed in large calories per kilogram to the nearest 0.1 calorie. The temperature of the room should be about 2° C. higher than the temperature of the water within the calorimeter.

The allowable percentage of variation is 5; the number of tests required is three. The result is expressed to the nearest 0.1 large calorie. The computation tolerance is 0.1 large calorie. The average result expressed to the nearest 0.1 large calorie.

The presence of red fumes in the bomb indicate the presence of oxides of nitrogen, which are formed when detonation is incomplete.

When there is any indication of incomplete detonation, increase the diameter of the charge to 2 inches and proceed with the tests until the results of three trials agree within 5 per cent, but in any event the tests should be discontinued as soon as three trials indicate incomplete detonation. Then a No. 8 electric detonator should be used with a charge having a diamete · of 2 inches. Discontinue the tests entirely when incomplete detonation is shown in two tests with a No. 8 electric detonator. The results of three trials agreeing within 5 per cent may include trials fired both with No. 7 and No. 8 electric detonators.

The correction to be subtracted when a No. 8 electric detonator is used is 1.14 calories.

HEAT DETERMINATIONS IN SUITABILITY TESTS.

Suitability tests are made in the same way as those for permissibility, with the following exceptions:

The electric detonator used is a No. 6 or stronger; however, with slow-burning explosives an electric igniter is used. The correction for a No 6 electric detonator is 0.62 calorie. The tests are made until the results of duplicate tests agree within 5 per cent.

TESTS WITH SMALL LEAD BLOCKS.

PERMISSIBILITY TESTS.

The small lead block test determines the relative quickness of an explosive, as indicated by the compression of the lead block.

Each lead block is a cylinder $1\frac{1}{2}$ inches (3.8 centimeters) in diameter and $2\frac{1}{2}$ inches (6.4 centimeters) in height. On the top of the block is placed a disk of annealed steel $1\frac{1}{2}$ inches in diameter and $\frac{1}{4}$ inch thick.

To the top of the block and to the under side of the disk a thin layer of vaseline is applied. The disk is then pressed tightly down on the block and the excess vaseline squeezed out is wiped off. The charge is held in a wrapper of Keystone fiber manila paper cut 6 inches square. The average weight of 10 such pieces should be 2.95 ± 0.15 grams. The paper is wrapped around the block and the disk in such a way that the bottom of the paper coincides with lower line marked on the block. The vertical edge is secured by paste, thus forming at the upper end a container for the explosive.

The weight of the charge is 100 ± 0.1 grams, which should be compressed in the container until it has the same specific gravity as that of the explosive in $1\frac{1}{4}$-inch cartridges. However, if the manufacturer has not submitted any $1\frac{1}{4}$-inch cartridges use the cartridge having a diameter the nearest to $1\frac{1}{4}$ inches. Should the testing engineer for any reason not be able to make his charge up to the specific gravity necessary, his record should state the reason for the discrepancy. Cut away and discard the ends and discolored parts of the original cartridge from which the charge is procured. A No. 7 electric detonator is embedded centrally in the top of the charge by making a hole deep enough so that it can be inserted three-fourths of an inch.

The height of the charge should be expressed to the nearest 0.1 centimeter and should correspond practically with the theoretical height required for the density of the charge as manufactured and the diameter of the blocks. (See Table 6, p. —.) The weight of the disk should be expressed to the nearest gram.

The height of the block before the shot, the height after the shot, and the compression should be observed to the nearest 0.25 millimeter for each of the four equal zones into which the block is divided. The time of firing should be stated. The allowable percentage of variation is 5, unless the compression is less than 20 millimeters, when the allowance of variation is 1 millimeter. The number of tests required is three. No. 7 electric detonators are used. The average result is expressed to 0.1 millimeter and 0.01 inch.

$$1 \text{ millimeter} = \frac{1}{25\ 4} = 0.0394 \text{ inch.}$$

For all small lead-block tests, after the record sheets are filed, the assistant engineer makes a work requisition on form 6–1 for seven prints of photographs of the blocks. The blocks are sent to the photographer at this time; the duplicate receipt cards request that they be photographed.

SUITABILITY TESTS.

Suitability tests are the same as those made for permissibility, except that the trials are made in duplicate within 5 per cent. No. 6 electric detonators are usually used. The weight of charge is 50 grams. Use Table 6 for height of charge.

TRAUZL LEAD BLOCKS.

The Trauzl lead-block test measures the comparative disruptive effect of an explosive when fired under moderate confinement in a small bore hole in a large lead block. It is used in testing explosives both for permissibility and suitability.

The explosive is carefully removed from its cartridge and 10 ± 0.01 grams weighed on a chemical balance. Do not use the ends or discolored parts of the explosive. The charge is wrapped in tin foil so as to make a cartridge 25 millimeters in diameter. The tin foil is cut in the shape of a trapezoid, with sides 150 and 130 millimeters long, and with a width of 70 millimeters.

The electric detonator is placed centrally in the charge. No. 7 electric detonator is used for testing explosives for permissibility and a No. 6 or stronger for testing explosives for suitability. After inserting the charge in the bore hole, pour in 40 cubic centimeters of dry sand, like that described on page —; tamp by 10 blows with the tamping device. An additional 10 cubic centimeters should be added and tamped by 40 blows from the tamping device. The lead blocks are always shot at a temperature of $15° \pm 2°$ C.

Each block is charged and fired separately. For each test the number of the block and the volume of the hole in cubic centimeters to the nearest cubic centimeter before and after shot is observed by drawing water from a calibrated burette. The increase in volume is computed to the nearest cubic centimeter. The time of firing shot should be stated and reference should be made to some previous test similarly conducted.

The allowable percentage of variation is 5.

The number of tests required is three for permissibility and two for suitability.

The average increase in volume is expressed to the nearest cubic centimeter and 0.01 cubic inch.

One cubic centimeter = 0.061 cubic inch.

TESTS WITH SMALL TRAUZL LEAD BLOCKS.

These blocks are used for testing detonators in the following manner:

Usually the lead blocks used are cylindrical in shape, 100 millimeters high, and 100 millimeters in diameter. The hole is bored in the block the exact diameter of the detonator and of such a depth that the top of the detonator is flush with the top of the block. The tests are reported on the same form as that used for reporting Trauzl lead blocks.

PENDULUM FRICTION TESTS.

PERMISSIBILITY TESTS.

The pendulum friction device is used for testing the sensitiveness of explosives when subjected to frictional impact or a glancing blow.

The shoe is first adjusted square with the plate so that it slides across the plate 18 ± 1 times when there is no explosive on the plate.

The charge of explosive is 7 ± 0.1 grams. Do not use the ends or discolored part of the explosive when taking a charge from the original wrapper.

The drop of the shoe is $1\frac{1}{2}$ meters. The weight added to the shoe is 20 kilograms. An explosive, to pass this test, must not in 10 trials give any evidence of explosion or burning, and any local cracking must be almost indistinguishable.

The steel shoe is tried first until the 10 trials have been made or until the test has shown that the explosive will not stand 10 trials. In the latter event the fiber shoe is used under the same conditions as the steel shoe. An explosive, to pass this test, must not give any unfavorable result with the fiber shoe; that is, it should show nothing more serious than an almost indistinguishable local cracking. When there is burning or explosion, the explosive will be considered unsatisfactory. The plate used is of soft steel. The minimum temperature of the plate and shoe shall be 14° C., and the maximum, 30° C.

SUITABILITY TESTS.

These tests are the same as those for permissibility, except that on special tests a carborundum-faced shoe may be used. For this purpose the shoe is faced with aloxite cloth.

TOLERANCE FOR PERMISSIBLE EXPLOSIVES.

Each explosive must pass a test of 10 trials under the same conditions as originally [a] tested, except that the height of fall of the wood-fiber shoe shall be reduced by 10 per cent.

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[a] When an explosive is submitted for test as to permissibility, the tests then made are regarded as original tests. Subsequent tests, for example, tests of explosions obtained in the field, are re-tests. Tolerances apply only to such re-tests.

DETERMINATION OF GASES EVOLVED IN TESTS.

PERMISSIBILITY TESTS.

The charge of explosive is fired in Bichel pressure bomb No. 1, and is 200 ± 0.5 grams of explosive plus the proportionate quantity of original wrapper, which corresponds to that quantity of wrapper for one of the sizes of cartridge that will give the maximum quantity of poisonous gases. Until the laws governing the production of the maximum quantity of poisonous gases are determined, more than one trial must be made, and trials with all quantities of wrapper, found by physical examination, must be made if the quantity of poisonous gases is close to 158 liters per 680 grams of charge. The ends and the discolored parts of the explosive in the original cartridges should be cut away and discarded.

The charge for slow explosives may be increased to 300 grams plus the proper amount of original wrapper, or of newspaper if the explosives are received in bulk. The diameter and the length of cartridge are measured to the nearest one-tenth of a centimeter. The density of the charge should correspond to the apparent specific gravity as shown in the physical examination.

The electric detonator used is a No. 7, except that with slow-burning explosives an electric igniter is used. When an igniter is used with a slow-burning explosive, it has been found impossible to ignite the explosive when a vacuum exists in the gage, although in practice an attempt should first be made to do so. Upon failure to get an ignition, the charge should be fired with the gage full of air at atmospheric pressure. The vacuum must be 50 ± 5 millimeters, which is the difference between the barometer and the manometer readings.

In order to be sure that there is a vacuum in the pressure bomb, the valve connection for the pressure gage on top of the bomb should be left open until after the vacuum pump has been started and air is sucking through the valve.

The pressure bomb should be perfectly dry before a shot. The temperature of the bomb should be given to the nearest degree centigrade, and the barometer reading to the nearest millimeter. When, for any reason, the barometer is not read, assume 740 millimeters of mercury. The time of firing and the calibration test number of the Rosenkrantz gage should be given. The gage should, if possible, be read to the nearest 0.01 kilogram per square centimeter five minutes after the shot is fired.

The gaseous products are drawn off from the bomb one-half hour after the shot is fired. A differential sample is collected by displacing mercury, which is accomplished by drawing the gas off while the pressure in the pressure bomb falls from the maximum to near zero.

A duplicate receipt card is made out giving the necessary information for the chemist who takes and analyzes the gas sample; one copy of this receipt is retained by the explosives section.

The test cards are held by the assistant engineer until a report of the analysis has been received. Should more than one analysis be made of the same sample, the one on which the computations are desired should be indicated before the test cards are sent to the technical service section.

The method of computing the total volume of gas and the volume of gases from 680 grams of explosive and wrapper is shown on the test record sheets (use also Table 8, p. 52)

The computation tolerance shall be ± 0.1 liter.

In case the explosive is fired in the bomb at atmospheric pressure, P_1 should be equal to (Pg × 736) + M, which conforms to formula given on the test record sheet (form 6–630).

TEST REQUIREMENT AS TO EVOLUTION OF GASES.

A 680-gram (1½-pound) charge of explosive must not evolve 158 liters (5½ cubic feet) or more of poisonous gases as determined by gage tests.

The poisonous gas usually evolved is carbon monoxide; some explosives also give off hydrogen sulphide.

TOLERANCES.

The volume of poisonous gases from 680 grams of the explosive, including its paper wrapper, must be less than 158 liters, except that if the first test yields 158 liters or more of poisonous gas per 680 grams of explosive, including its wrapper, the average result of three tests agreeing within 5 per cent of each other shall be taken, and no explosive shall remain permissible when this average for poisonous gases exceeds the standard limit mentioned.

SUITABILITY TESTS.

The suitability tests are made like the permissibility tests, with the following exceptions:

The electric detonator used is a No. 6 or stronger, except that with slow-burning explosives electric igniters are used.

The volumes of total and poisonous gases are computed for 454 grams (1 pound) of the explosive, including its wrapper.

MISCELLANEOUS TESTS.

All tests not run under other designations come under this heading. The most important tests are calibrations of the different sets of apparatus. The index fraction in the numerator gives the key number of the apparatus.

BURNING TESTS.

Surplus explosive is usually destroyed by burning. A number of different methods have been tried, the two principal ones being as described below.

One of these is known as "V–70 in salamander." Two ½-pound or four ¼-pound cartridges of explosive are taken and dropped together in a fire of soft coal in a salamander. The salamander is placed under one of the doors of the gas-and-dust gallery No. 1, or in the Forbes Field gallery.

The other principal burning test is known as V–466. Paper is placed on the ground; the cartridges, the weight of which should not exceed 2 pounds, are opened and the contents spread in a thin layer on the paper. The explosive is saturated with kerosene. In order to ignite the explosive, place on the edge of the layer 25 grams of black blasting powder and place an igniter in contact with the powder. The firing machine for firing the igniter should be at a safe distance—not less than 60 feet.

The time it takes the explosive to burn should be recorded.

In all tests the condition of the explosive should be stated and whether it is frozen. In cold weather, state whether the explosive has been placed in the thawer. State the temperature of the atmospheric air, and whether the explosive burns without exploding.

STORAGE TESTS.

Two, four, and six month storage tests are made where practicable on all explosives received for tests. Any five cartridges of the smallest diameter of cartridge submitted are separately suspended in air in a gallery and fired by means of the electric detonator recommended by the manufacturer. The record should show the diameter of cartridge used. These tests are considered more severe than those made in a cannon; therefore no further tests are made if there is complete detonation in each of the five trials, as the explosive is then considered to have passed the test.

However, if some of these cartridges fail to detonate completely, the number thus failing is noted, and the same number of fresh cartridges are fired separately in a cannon charged air-spaced, and the number and the nature of the failures are again noted. For each failure, fresh cartridges are now taken and loaded with a density of 1 in a cannon and fired separately as before. If there are two or more failures the explosive fails to pass the test.

The condition of all cartridges used in these tests should be stated.

If an explosive is to be placed on the permissible list, two or more charges must not fail to detonate or explode completely in the course of official tests, and the explosive must pass the two months' storage tests.

CRUSHER-BOARD TESTS.

Crusher-board tests are made on those explosives denominated low freezing, extra low freezing, or nonfreezing. These tests give the relative compressive strength of the cartridges. Three cartridges are tested when in each of the following conditions: (1) At room temperature; (2) after having been kept for several hours at low temperatures after removal from a thawer. The prescribed low temperatures are 35° F. for low-freezing explosives; 0° F. for extra low-freezing explosives; and lower temperatures for nonfreezing explosives.

In cold weather cartridges should also be tested directly after removal from the magazine. The test cards should show the method of procedure; the weight producing the first crack, and the weight of the top board are expressed to the nearest 0.1 kilogram. If practicable, 1¼-inch cartridges should be used and a section 10 centimeters long should be taken out of the central part of the cartridge by cutting the explosive with a knife before freezing it or attempting to freeze it; if this is impracticable, by reason of the consistency of the explosive, it should be tested without cutting.

The testing engineer should state whether the explosive shows any sign of being frozen.

NAIL TEST.

This test depends on the angle formed by a nail when a detonator or electric detonator is fired in close proximity to the nail.

Four-inch (20d.) wire finishing nails are used in the test. The nails should be carefully selected so that they have approximately the same length, gage, and weight. The bottom of the electric detonator is placed 1¾ inches from the face of the head of the nail, the detonator being parallel to the nail and separated from it by two 22-gage (0.025-inch) copper wires, which are wrapped around the detonator and fastened together by a similar piece of wire wrapped around both of them at a point midway between the ends of the detonator. The whole is suspended horizontally in the air in such a manner that the nail is directly above the detonator. Five trials are made with each grade of detonator. The angle to which the nail is bent is measured to the nearest 0.25 degree by a protractor after the angle has been traced on paper, and the average of five angles is computed to the nearest 0.25 degree.

TESTS IN FORBES FIELD GALLERY.

These tests are recorded in the same way as those at gas-and-dust gallery No. 1, and comprise demonstration shots made at this gallery.

TESTS AT GAS-AND-DUST GALLERY NO. 3.

This gallery consists essentially of a steel box measuring 18 by 18 by 24 inches, having in front two plate-glass observation windows.

One end of this box is closed by a square diaphragm of paraffin-coated paper. A fan connected to the gallery by two pipes entering at opposite sides is used to insure thorough mixing of the gas and air.

Tests at this gallery have been largely of an experimental nature, with fuse and fuse igniters, and no standard tests have been established.

TEST FOR RATE OF BURNING.

This test is usually applied to black blasting powder. Various methods have been devised and tried, but standard tests have not been established.

SCREENING TESTS.

Screening tests are usually made only of black blasting powder in a separator designed for the purpose.

The weight of powder put in separator is given to the nearest gram. The time the powder is kept out of container is given to the nearest minute. The weight of each size obtained is given to the nearest gram. The percentages should be computed to the nearest 0.01 per cent.

CONVERSION TABLES USED IN EXPLOSIVES WORK.

The tables following are constantly used in connection with the testing of explosives by the Bureau of Mines:

TABLE 1.—*Table for obtaining volume of cartridge in cubic centimeters from grams of sand[a] displaced.*

[Example: If weight of sand displaced=162 grams, volume of cartridge=114 c. c.]

		0	1	2	3	4	5	6	7	8	9			0	1	2	3	4	5	6	7	8	9
10	0	70	71	72	73	73	74	75	75	76	77	40	2	82	82	83	84	85	85	86	87	87	88
11		77	78	79	80	80	81	82	82	83	84	41		89	89	90	91	92	92	93	94	94	95
12		85	85	86	87	87	88	89	89	90	91	42		96	96	97	98	99	99	[b]00	[c]01	[c]01	[c]02
13		92	92	93	94	94	95	96	96	97	98												
												43	3	03	04	04	05	06	06	07	08	08	09
14	1	[b]99	[b]99	00	01	01	02	03	04	04	05	44		10	11	11	12	13	13	14	15	15	16
15		06	06	07	08	08	09	10	11	11	12	45		17	18	18	19	20	20	21	22	23	23
16		13	13	14	15	15	16	17	18	18	19	46		24	25	25	26	27	27	28	29	30	30
17		20	20	21	22	23	23	24	25	25	26	47		31	32	32	33	34	35	35	36	37	37
18		27	27	28	29	30	30	31	32	32	33	48		38	39	39	40	41	42	42	43	44	44
19		34	35	35	36	37	37	38	39	39	40	49		45	46	46	47	48	49	49	50	51	51
20		41	42	42	43	44	44	45	46	46	47	50		52	53	54	54	55	56	56	57	58	58
21		48	49	49	50	51	51	52	53	54	54	51		59	60	61	61	62	63	63	64	65	65
22		55	56	56	57	58	58	59	60	61	61	52		66	67	68	68	69	70	70	71	72	73
23		62	63	63	64	65	65	66	67	68	68	53		73	74	75	75	76	77	77	78	79	80
24		69	70	70	71	72	73	73	74	75	75	54		80	81	82	82	83	84	85	85	86	87
25		76	77	77	78	79	80	80	81	82	82	55		87	88	89	89	90	91	92	92	93	94
26		83	84	85	85	86	87	87	88	89	89	56		94	95	96	96	97	98	99	99	[c]00	[c]01
27		90	91	92	92	93	94	94	95	96	96												
												57	4	01	02	03	04	04	05	06	06	07	08
28	2	[b]97	[b]98	[b]99	[b]99	00	01	01	02	03	04	58		08	09	10	11	11	12	13	13	14	15
29		04	05	06	06	07	08	08	09	10	11	59		15	16	17	18	18	19	20	20	21	22
30		11	12	13	13	14	15	15	16	17	18	60		23	23	24	25	25	26	27	27	28	29
31		18	19	20	20	21	22	23	23	24	25	61		30	30	31	32	32	33	34	35	35	36
32		25	26	27	27	28	29	30	30	31	32	62		37	37	38	39	39	40	41	42	42	43
33		32	33	34	35	35	36	37	37	38	39	63		44	44	45	46	46	47	48	49	49	50
34		39	40	41	42	42	43	44	44	45	46	64		51	51	52	53	54	54	55	56	56	57
35		46	47	48	49	49	50	51	51	52	53	65		58	58	59	60	61	61	62	63	63	64
36		54	54	55	56	56	57	58	58	59	60	66		65	65	66	67	68	68	69	70	70	71
37		61	61	62	63	63	64	65	65	66	67	67		72	73	73	74	75	75	76	77	77	78
38		68	68	69	70	70	71	72	73	73	74	68		79	80	80	81	82	82	83	84	85	85
39		75	75	76	77	77	78	79	80	80	81	69		86	87	87	88	89	89	90	91	92	92

[a] Specific gravity of sand, 1.42.

[b] Index figure should be 1 less than figure in second column. To illustrate, if the weight of sand displaced is 141 grams, the volume of the cartridge is 0.99 c. c.

[c] Index figure should be 1 more than figure in second column.

TABLE 2.—*Table for converting distances between spark points in millimeters into rate of detonation in meters per second when peripheral speed of drum is 45 meters per second.*

[Example: If the given spark-point distance is 14.85 mm. the rate of detonation is 3030 meters per second.]

	0	1	2	3	4	5	6	7	8	9
5.0	9000	8982	8964	8946	8929	8911	8893	8876	8858	8841
5.1	8824	8806	8789	8772	8755	8738	8721	8704	8687	8671
5.2	8654	8637	8621	8604	8588	8571	8555	8539	8523	8507
5.3	8491	8475	8459	8443	8427	8411	8396	8380	8364	8349
5.4	8333	8318	8303	8287	8272	8257	8242	8227	8212	8197
5.5	8182	8167	8152	8137	8123	8108	8094	8079	8065	8050
5.6	8036	8021	8007	7993	7979	7965	7951	7937	7923	7909
5.7	7895	7881	7867	7853	7840	7826	7812	7799	7785	7772
5.8	7759	7745	7732	7719	7705	7692	7679	7666	7653	7640
5.9	7627	7614	7601	7589	7576	7563	7550	7538	7525	7513
6.0	7500	7488	7475	7463	7450	7438	7426	7414	7401	7389
6.1	7377	7365	7353	7341	7329	7317	7305	7293	7282	7270
6.2	7258	7246	7235	7223	7212	7200	7188	7177	7166	7154
6.3	7143	7132	7120	7109	7098	7087	7075	7064	7053	7042
6.4	7031	7020	7009	6999	6988	6977	6966	6955	6944	6934
6.5	6923	6912	6902	6891	6881	6870	6860	6849	6839	6829
6.6	6818	6808	6798	6787	6777	6767	6757	6747	6737	6726
6.7	6716	6706	6696	6686	6677	6667	6657	6647	6637	6627
6.8	6618	6608	6598	6589	6579	6569	6560	6550	6541	6531
6.9	6522	6512	6503	6494	6484	6475	6466	6456	6447	6438
7.0	6429	6419	6410	6401	6392	6383	6374	6365	6356	6347
7.1	6338	6329	6320	6311	6303	6294	6285	6276	6267	6259
7.2	6250	6241	6233	6224	6215	6207	6198	6190	6181	6173
7.3	6164	6156	6148	6139	6131	6122	6114	6106	6098	6089
7.4	6081	6073	6065	6057	6048	6040	6032	6024	6016	6008
7.5	6000	5992	5984	5976	5968	5960	5952	5945	5937	5929
7.6	5921	5913	5906	5898	5890	5882	5875	5867	5859	5852
7.7	5844	5837	5829	5821	5814	5806	5799	5792	5784	5777
7.8	5769	5762	5754	5747	5740	5732	5725	5718	5711	5703
7.9	5696	5689	5682	5675	5668	5660	5653	5646	5639	5632
8.0	5625	5618	5611	5604	5597	5590	5583	5576	5569	5562
8.1	5556	5549	5542	5535	5528	5521	5515	5508	5501	5495
8.2	5488	5481	5474	5468	5461	5455	5448	5441	5435	5428
8.3	5422	5415	5409	5402	5396	5389	5383	5376	5370	5364
8.4	5357	5351	5344	5338	5332	5325	5319	5313	5307	5300
8.5	5294	5288	5282	5275	5269	5263	5257	5251	5245	5239
8.6	5233	5226	5220	5214	5208	5202	5196	5190	5184	5178
8.7	5172	5166	5161	5155	5149	5143	5137	5131	5125	5119
8.8	5114	5108	5102	5096	5090	5085	5079	5073	5068	5062
8.9	5056	5051	5045	5039	5034	5028	5022	5017	5011	5006
9.0	5000	4994	4989	4983	4978	4972	4967	4961	4956	4951
9.1	4945	4940	4934	4929	4923	4918	4913	4907	4902	4897
9.2	4891	4886	4881	4875	4870	4865	4860	4854	4849	4844
9.3	4839	4834	4828	4823	4818	4813	4808	4803	4797	4792
9.4	4787	4782	4777	4772	4767	4762	4757	4752	4747	4742
9.5	4737	4732	4727	4722	4717	4712	4707	4702	4697	4692
9.6	4688	4683	4678	4673	4668	4663	4658	4654	4649	4644
9.7	4639	4634	4630	4625	4620	4615	4611	4606	4601	4596
9.8	4592	4587	4582	4578	4573	4569	4564	4559	4555	4550
9.9	4545	4541	4536	4532	4527	4523	4518	4514	4509	4505
10.0	4500	4496	4491	4487	4482	4478	4473	4469	4464	4460
10.1	4455	4451	4447	4442	4438	4433	4429	4425	4420	4416
10.2	4412	4407	4403	4399	4395	4390	4386	4382	4377	4373
10.3	4369	4365	4360	4356	4352	4348	4344	4339	4335	4331
10.4	4327	4323	4319	4314	4310	4306	4302	4298	4294	4290
10.5	4286	4282	4278	4273	4269	4265	4261	4257	4253	4249
10.6	4245	4241	4237	4233	4229	4225	4221	4217	4213	4210
10.7	4206	4202	4198	4194	4190	4186	4182	4178	4174	4171
10.8	4167	4163	4159	4155	4151	4147	4144	4140	4136	4132
10.9	4128	4125	4121	4117	4113	4110	4106	4102	4098	4095
11.0	4091	4087	4083	4080	4076	4072	4069	4065	4061	4058
11.1	4054	4050	4047	4043	4039	4036	4032	4029	4025	4021
11.2	4018	4014	4011	4007	4004	4000	3996	3993	3989	3986
11.3	3982	3979	3975	3972	3968	3965	3961	3958	3954	3951
11.4	3947	3944	3940	3937	3934	3930	3927	3923	3920	3916
11.5	3913	3910	3906	3903	3899	3896	3893	3889	3886	3883
11.6	3879	3876	3873	3869	3866	3863	3859	3856	3853	3849
11.7	3846	3843	3840	3836	3833	3830	3827	3823	3820	3817
11.8	3814	3810	3807	3804	3801	3797	3794	3791	3788	3785
11.9	3782	3778	3775	3772	3769	3766	3763	3759	3756	3753
12.0	3750	3747	3744	3741	3738	3734	3731	3728	3725	3722
12.1	3719	3716	3713	3710	3707	3704	3701	3698	3695	3692
12.2	3689	3686	3682	3679	3676	3673	3670	3667	3664	3662
12.3	3659	3656	3653	3650	3647	3644	3641	3638	3635	3632
12.4	3629	3626	3623	2620	3617	3614	3612	3609	3606	3603
12.5	3600	3597	3594	3591	3589	3586	3583	3580	3577	3574
12.6	3571	3569	3566	3563	3560	3557	3555	3552	3549	3546
12.7	3543	3541	3538	3535	3532	3529	3527	3524	3521	3518
12.8	3516	3513	3510	3507	3505	3502	3499	3497	3494	3491
12.9	3488	3486	3483	3480	3478	3475	3472	3470	3467	3464
13.0	3462	3459	3456	3454	3451	3448	3446	3443	3440	3438
13.1	3435	3432	3430	3427	3425	3422	3419	3417	3414	3412
13.2	3409	3407	3404	3401	3399	3396	3394	3391	3389	3386
13.3	3383	3381	3378	3376	3373	3371	3368	3366	3363	3361
13.4	3358	3356	3353	3351	3348	3346	3343	3341	3338	3336
13.5	3333	3331	3328	3326	3323	3321	3319	3316	3314	3311
13.6	3309	3306	3304	3302	3299	3297	3294	3292	3289	3287
13.7	3285	3282	3280	3277	3275	3273	3270	3268	3266	3263
13.8	3261	3259	3256	3254	3251	3249	3247	3244	3242	3240
13.9	3237	3235	3233	3230	3228	3226	3223	3221	3219	3217
14.0	3214	3212	3210	3207	3205	3203	3201	3198	3196	3194
14.1	3191	3189	3187	3185	3182	3180	3178	3176	3173	3171
14.2	3169	3167	3165	3162	3160	3158	3156	3153	3151	3149
14.3	3147	3145	3142	3140	3138	3136	3134	3132	3129	3127
14.4	3125	3123	3121	3119	3116	3114	3112	3110	3108	3106
14.5	3103	3101	3099	3097	3095	3093	3091	3089	3086	3084
14.6	3082	3080	3078	3076	3074	3072	3070	3067	3065	3063
14.7	3061	3059	3057	3055	3053	3051	3049	3047	3045	3043
14.8	3041	3038	3036	3034	3032	3030	3028	3026	3024	3022
14.9	3020	3018	3016	3014	3012	3010	3008	3006	3004	3002
15.0	3000	2998	2996	2994	2992	2990	2988	2986	2984	2982
15.1	2980	2978	2976	2974	2972	2970	2968	2966	2964	2962
15.2	61	59	57	55	53	51	49	47	45	43
15.3	41	39	37	35	33	32	30	28	26	24
15.4	22	20	18	16	15	13	11	09	07	05
15.5	2903	2901	2900	2898	2896	2894	2892	2890	2888	2887
15.6	2885	2883	2881	2879	2877	2875	2874	2872	2870	2868
15.7	66	64	63	61	59	57	55	54	52	50
15.8	48	46	45	43	41	39	37	36	34	32
15.9	30	28	27	25	23	21	20	18	16	14
16.0	2813	2811	2809	2807	2805	2804	2802	2800	2799	2797
16.1	2795	2793	2792	2790	2788	2786	2785	2783	2781	2779
16.2	78	76	74	73	71	69	68	66	64	62
16.3	61	59	57	56	54	52	51	49	47	46
16.4	44	42	41	39	37	36	34	32	31	29
16.5	27	26	24	22	21	19	17	16	14	12
16.6	2711	2709	2708	2706	2705	2703	2701	2699	2698	2696
16.7	2695	2693	2691	2690	2688	2687	2685	2683	2682	2680
16.8	79	77	75	74	72	71	69	67	66	64
16.9	63	61	60	58	56	55	53	52	50	49
17.0	47	46	44	42	41	39	38	36	35	33
17.1	32	30	29	27	25	24	22	21	19	18
17.2	16	15	13	12	10	09	07	06	04	03
17.3	2601	2600	2598	2597	2595	2594	2592	2591	2589	2588
17.4	2586	2585	2583	2582	2580	2579	2577	2576	2574	2573
17.5	71	70	68	67	66	64	63	61	60	58
17.6	57	55	54	52	51	50	48	47	45	44
17.7	42	41	40	38	37	35	34	32	31	30
17.8	28	27	25	24	23	21	20	18	17	15
17.9	14	13	11	10	08	07	06	04	03	01

TABLE 2.—*Table for converting distances between spark points in millimeters into rate of detonation in meters per second when peripheral speed of drum is 45 meters per second*—Continued.

	0	1	2	3	4	5	6	7	8	9
18.0	2500	2499	2497	2496	2494	2493	2492	2490	2489	2488
18.1	2486	2485	2483	2482	2481	2479	2478	2477	2475	2474
18.2	73	71	70	68	67	66	64	63	62	60
18.3	59	58	56	55	54	52	51	50	48	47
18.4	46	44	43	42	40	39	38	36	35	34
18.5	32	31	30	28	27	26	25	23	22	21
18.6	19	18	17	15	14	13	12	10	09	08
18.7	2406	2405	2404	2402	2401	2400	2399	2397	2396	2395
18.8	2394	2392	2391	2390	2389	2387	2386	2385	2384	2382
18.9	81	80	78	77	76	75	73	72	71	70
19.0	68	67	66	65	63	62	61	60	58	57
19.1	56	55	54	52	51	50	49	47	46	45
19.2	44	43	41	40	39	38	36	35	34	33
19.3	32	30	29	28	27	26	24	23	22	21
19.4	20	18	17	16	15	14	12	11	10	09
19.5	2308	2307	2305	2304	2303	2302	2301	2299	2298	2297
19.6	2296	2295	2294	2292	2291	2290	2289	2288	2287	2285
19.7	84	83	82	81	80	79	77	76	75	74
19.8	73	72	70	69	68	67	66	65	64	62
19.9	61	60	59	58	57	56	55	53	52	51
20.0	2250	2249	2248	2247	2246	2244	2243	2242	2241	2240
20.1	39	38	37	35	34	33	32	31	30	29
20.2	28	27	26	24	23	22	21	20	19	18
20.3	17	16	15	13	12	11	10	09	08	07
20.4	2206	2205	2204	2203	2202	2200	2199	2198	2197	2196
20.5	2195	2194	2193	2192	2191	2190	2189	2188	2187	2186
20.6	84	83	82	81	80	79	78	77	76	75
20.7	74	73	72	71	70	69	68	67	66	65
20.8	63	62	61	60	59	58	57	56	55	54
20.9	53	52	51	50	49	48	47	46	45	44
21.0	43	42	41	40	39	38	37	36	35	34
21.1	33	32	31	30	29	28	27	26	25	24
21.2	23	22	21	20	19	18	17	16	15	14
21.3	13	12	11	10	09	08	07	06	05	04
21.4	2103	2102	2101	2100	2099	2098	2097	2096	2095	2094
21.5	2093	2092	2091	2090	2089	2088	2087	2086	2085	2084
21.6	83	82	81	80	79	79	78	77	76	75
21.7	74	73	72	71	70	69	68	67	66	65
21.8	64	63	62	61	60	59	59	58	57	56
21.9	55	54	53	52	51	50	49	48	47	46
22.0	45	45	44	43	42	41	40	39	38	37
22.1	36	35	34	33	33	32	31	30	29	28
22.2	27	26	25	24	23	22	22	21	20	19
22.3	18	17	16	15	14	13	13	12	11	10
22.4	09	08	07	06	05	04	04	03	02	01
22.5	2000	1999	1998	1997	1996	1996	1995	1994	1993	1992
22.6	1991	1990	1989	1989	1988	1987	1986	1985	1984	1983
22.7	82	82	81	80	79	78	77	76	75	75
22.8	74	73	72	71	70	69	69	68	67	66
22.9	65	64	63	62	62	61	60	59	58	57
23.0	57	56	55	54	53	52	51	51	50	49
23.1	48	47	46	46	45	44	43	42	41	40
23.2	40	39	38	37	36	35	35	34	33	32
23.3	31	31	30	29	28	27	26	26	25	24
23.4	23	22	21	21	20	19	18	17	17	16
23.5	15	14	14	13	12	11	10	09	08	08
23.6	1907	1906	1905	1904	1904	1903	1902	1901	1900	1900
23.7	1899	1898	1897	1896	1896	1895	1894	1893	1892	1892
23.8	91	90	89	88	88	87	86	85	84	84
23.9	83	82	81	80	79	79	78	77	77	76
24.0	75	74	73	73	72	71	70	70	69	68
24.1	67	66	66	65	64	63	63	62	61	60
24.2	60	59	58	57	56	56	55	54	53	53
24.3	52	51	50	50	49	48	47	47	46	45
24.4	44	44	43	42	41	40	40	39	38	37

	0	1	2	3	4	5	6	7	8	9
24.5	37	36	35	34	34	33	32	32	31	30
24.6	29	29	28	27	26	26	25	24	23	23
24.7	22	21	20	20	19	18	17	17	16	15
24.8	15	14	13	12	12	11	10	09	09	08
24.9	07	07	06	05	04	04	03	02	01	01
25.0	1800	1799	1799	1798	1797	1796	1796	1795	1794	1794
25.1	1793	1792	1791	1791	1790	1789	1789	1788	1787	1786
25.2	86	85	84	84	83	82	81	81	80	79
25.3	79	78	77	77	76	75	74	74	73	72
25.4	72	71	70	70	69	68	67	67	66	65
25.5	65	64	63	63	62	61	61	60	59	58
25.6	58	57	56	56	55	54	54	53	52	52
25.7	51	50	50	49	48	48	47	46	46	45
25.8	44	44	43	43	42	42	40	39	39	38
25.9	37	37	36	35	35	34	33	33	32	31
26.0	31	30	29	29	28	27	27	26	25	25
26.1	24	23	23	22	21	21	20	20	19	18
26.2	18	17	16	16	15	14	14	13	12	12
26.3	11	10	10	09	08	08	07	06	06	05
26.4	1705	1704	1703	1703	1702	1701	1701	1700	1699	1699
26.5	1698	1697	1697	1696	1696	1695	1694	1694	1693	1692
26.6	92	91	90	90	89	89	88	87	87	86
26.7	85	85	84	84	83	82	82	81	80	80
26.8	79	79	78	77	77	76	75	75	74	73
26.9	73	72	72	71	70	70	69	69	68	67
27.0	67	66	65	65	64	64	63	62	62	61
27.1	61	60	59	59	58	57	57	56	56	55
27.2	54	54	53	53	52	51	51	50	50	49
27.3	48	48	47	47	46	45	45	44	44	43
27.4	42	42	41	41	40	39	39	38	38	37
27.5	1636	1636	1635	1635	1634	1633	1633	1632	1632	1631
27.6	30	30	29	29	28	27	27	26	26	25
27.7	25	24	23	23	22	22	21	20	20	19
27.8	19	18	18	17	16	16	15	15	14	14
27.9	13	12	12	11	11	10	09	09	08	08
28.0	07	07	06	05	05	04	04	03	03	02
28.1	1601	1601	1600	1600	1599	1599	1598	1597	1597	1596
28.2	1596	1595	1595	1594	1594	1593	1592	1592	1591	1591
28.3	90	90	89	88	88	87	87	86	86	85
28.4	85	84	83	83	82	82	81	81	80	80
28.5	79	78	78	77	77	76	76	75	75	74
28.6	73	73	72	72	71	71	70	70	69	69
28.7	68	67	67	66	66	65	65	64	64	63
28.8	63	62	61	61	60	60	59	59	58	58
28.9	57	57	56	55	55	54	54	53	53	52
29.0	52	51	51	50	50	49	49	48	47	47
29.1	46	46	45	45	44	44	43	43	42	42
29.2	41	41	40	40	39	38	38	37	37	36
29.3	36	35	35	34	34	33	33	32	32	31
29.4	31	30	30	29	29	28	28	27	26	26
29.5	25	25	24	24	23	23	22	22	21	21
29.6	20	20	19	19	18	18	17	17	16	16
29.7	15	15	14	14	13	13	12	12	11	11
29.8	10	10	09	09	08	08	07	07	06	06
29.9	05	05	04	04	03	03	02	02	01	01
30.0	1500	1500	1499	1499	1498	1498	1497	1497	1496	1496
30.1	1495	1495	1494	1494	1493	1493	1492	1492	1491	1491
30.2	90	90	89	89	88	88	87	87	86	86
30.3	85	85	84	84	83	83	82	82	81	81
30.4	80	80	79	79	78	78	77	77	76	76
30.5	75	75	74	74	73	73	73	72	72	71
30.6	71	70	70	69	69	68	68	67	67	66
30.7	66	65	65	64	64	63	63	62	62	62
30.8	61	61	60	60	59	59	58	58	57	57
30.9	56	56	55	55	54	54	53	53	53	52

TABLE 2.—*Table for converting distances between spark points in millimeters into rate of detonation in meters per second when peripheral speed of drum is 45 meters per second.*—Continued.

	0	1	2	3	4	5	6	7	8	9
31.0	52	51	51	50	50	49	49	48	48	47
31.1	47	46	46	46	45	45	44	44	43	43
31.2	42	42	41	41	40	40	40	39	39	38
31.3	38	37	37	36	36	35	35	34	34	34
31.4	33	33	32	32	31	31	30	30	29	29
31.5	29	28	28	27	27	26	26	25	25	25
31.6	24	24	23	23	22	22	21	21	20	20
31.7	20	19	19	18	18	17	17	16	16	16
31.8	15	15	14	14	13	13	12	12	12	11
31.9	11	10	10	09	09	08	08	08	07	07
32.0	06	06	05	05	04	04	04	03	03	02
32.1	1402	1401	1401	1401	1400	1400	1399	1399	1398	1398
32.2	1398	1397	1397	1396	1396	1395	1395	1394	1394	1394
32.3	93	93	92	92	91	91	91	90	90	89
32.4	89	88	88	88	87	87	86	86	85	85
32.5	85	84	84	83	83	82	82	82	81	81
32.6	80	80	80	79	79	78	78	77	77	77
32.7	76	76	75	75	74	74	74	73	73	72
32.8	72	72	71	71	70	70	69	69	69	68
32.9	68	67	67	67	66	66	65	65	64	64
33.0	64	63	63	62	62	62	61	61	60	60
33.1	60	59	59	58	58	57	57	57	56	56
33.2	55	55	55	54	54	53	53	53	52	52
33.3	51	51	51	50	50	49	49	49	48	48
33.4	47	47	46	46	46	45	45	44	44	44
33.5	43	43	42	42	42	41	41	40	40	40
33.6	39	39	38	38	38	37	37	37	36	36
33.7	35	35	35	34	34	33	33	33	32	32
33.8	31	31	31	30	30	29	29	29	28	28
33.9	27	27	27	26	26	25	25	25	24	24
34.0	24	23	23	22	22	22	21	21	20	20
34.1	20	19	19	18	18	18	17	17	17	16
34.2	16	15	15	15	14	14	13	13	13	12
34.3	12	12	11	11	10	10	10	09	09	09
34.4	08	08	07	07	07	06	06	05	05	05
34.5	04	04	04	03	03	02	02	02	01	01
34.6	1301	1300	1300	1299	1299	1299	1298	1298	1298	1297
34.7	1297	1296	1296	1296	1295	1295	1295	1294	1294	1293
34.8	93	93	92	92	92	91	91	91	90	90
34.9	89	89	89	88	88	88	87	87	86	86
35.0	1286	1285	1285	1285	1284	1284	1284	1283	1283	1282
35.1	82	82	81	81	81	80	80	79	79	79
35.2	78	78	78	77	77	77	76	76	76	75
35.3	75	74	74	74	73	73	73	72	72	72
35.4	71	71	70	70	70	69	69	69	68	68
35.5	68	67	67	67	66	66	65	65	65	64
35.6	64	64	63	63	63	62	62	62	61	61
35.7	61	60	60	59	59	59	58	58	58	57
35.8	57	57	56	56	56	55	55	55	54	54
35.9	53	53	53	52	52	52	51	51	51	50
36.0	50	50	49	49	49	48	48	48	47	47
36.1	47	46	46	46	45	45	44	44	44	43
36.2	43	43	42	42	42	41	41	41	40	40
36.3	40	39	39	39	38	38	38	37	37	37
36.4	36	36	36	35	35	35	34	34	34	33
36.5	33	33	32	32	32	31	31	31	30	30
36.6	30	29	29	29	28	28	27	27	27	26
36.7	26	26	25	25	25	24	24	24	23	23
36.8	23	22	22	22	21	21	21	21	20	20
36.9	20	19	19	19	18	18	18	17	17	17
37.0	16	16	16	15	15	15	14	14	14	13
37.1	13	13	12	12	12	11	11	11	10	10
37.2	10	09	09	09	08	08	08	07	07	07
37.3	06	06	06	05	05	05	04	04	04	04
37.4	03	03	03	02	02	02	01	01	01	00
37.5	1200	1200	1199	1199	1199	1198	1198	1198	1197	1197
37.6	1197	1197	1196	1196	1196	1195	1195	1195	1194	1194
37.7	94	93	93	93	92	92	92	91	91	91
37.8	91	90	90	90	89	89	89	88	88	88
37.9	87	87	87	86	86	86	85	85	85	85

	0	1	2	3	4	5	6	7	8	9
38.0	84	84	84	83	83	83	82	82	82	81
38.1	81	81	81	80	80	80	79	79	79	78
38.2	78	78	77	77	77	77	76	76	76	75
38.3	75	75	74	74	74	73	73	73	73	72
38.4	72	72	71	71	71	70	70	70	69	69
38.5	69	69	68	68	68	67	67	67	66	66
38.6	66	66	65	65	65	64	64	64	63	63
38.7	63	63	62	62	62	61	61	61	60	60
38.8	60	60	59	59	59	58	58	58	57	57
38.9	57	57	56	56	56	55	55	55	55	54
39.0	54	54	53	53	53	52	52	52	52	51
39.1	51	51	50	50	50	49	49	49	49	48
39.2	48	48	47	47	47	47	46	46	46	45
39.3	45	45	44	44	44	44	43	43	43	42
39.4	42	42	42	41	41	41	40	40	40	40
39.5	39	39	39	38	38	38	38	37	37	37
39.6	36	36	36	36	35	35	35	34	34	34
39.7	34	33	33	33	32	32	32	32	31	31
39.8	31	30	30	30	30	29	29	29	28	28
39.9	28	28	27	27	27	26	26	26	26	25
40.0	1125	1125	1124	1124	1124	1124	1123	1123	1123	1122
40.1	22	22	22	21	21	21	21	20	20	20
40.2	19	19	19	19	18	18	18	17	17	17
40.3	17	16	16	16	16	15	15	15	14	14
40.4	14	14	13	13	13	12	12	12	12	11
40.5	11	11	11	10	10	10	09	09	09	09
40.6	08	08	08	08	07	07	07	06	06	06
40.7	06	05	05	05	05	04	04	04	03	03
40.8	03	03	02	02	02	02	01	01	01	01
40.9	1100	1100	1100	1099	1099	1099	1099	1098	1098	1098
41.0	1098	1097	1097	1097	1096	1096	1096	1096	1095	1095
41.1	95	95	94	94	94	94	93	93	93	92
41.2	92	92	92	91	91	91	91	90	90	90
41.3	90	89	89	89	89	88	88	88	87	87
41.4	87	87	86	86	86	86	85	85	85	85
41.5	84	84	84	84	83	83	83	83	82	82
41.6	82	81	81	81	81	80	80	80	80	79
41.7	79	79	79	78	78	78	78	77	77	77
41.8	77	76	76	76	76	75	75	75	74	74
41.9	74	74	73	73	73	73	72	72	72	72
42.0	71	71	71	71	70	70	70	70	69	69
42.1	69	69	68	68	68	68	67	67	67	67
42.2	66	66	66	66	66	65	65	65	64	64
42.3	64	64	63	63	63	63	62	62	62	62
42.4	61	61	61	61	60	60	60	60	59	59
42.5	59	59	58	58	58	58	57	57	57	57
42.6	56	56	56	56	55	55	55	55	54	54
42.7	54	54	53	53	53	53	52	52	52	52
42.8	51	51	51	51	50	50	50	50	49	49
42.9	49	49	48	48	48	48	47	47	47	47
43.0	47	46	46	46	46	45	45	45	45	44
43.1	44	44	44	43	43	43	43	42	42	42
43.2	42	41	41	41	41	40	40	40	40	40
43.3	39	39	39	39	38	38	38	38	37	37
43.4	37	37	36	36	36	36	35	35	35	35
43.5	34	34	34	34	34	33	33	33	33	32
43.6	32	32	32	31	31	31	31	30	30	30
43.7	30	30	29	29	29	29	28	28	28	28
43.8	27	27	27	27	26	26	26	26	26	25
43.9	25	25	25	24	24	24	24	23	23	23
44.0	23	22	22	22	22	22	21	21	21	21
44.1	20	20	20	20	19	19	19	19	19	18
44.2	18	18	18	17	17	17	17	16	16	16
44.3	16	16	15	15	15	15	14	14	14	14
44.4	14	13	13	13	13	12	12	12	12	11
44.5	11	11	11	11	10	10	10	10	09	09
44.6	09	09	09	08	08	08	08	07	07	07
44.7	07	06	06	06	06	06	05	05	05	05
44.8	04	04	04	04	04	03	03	03	03	02
44.9	02	02	02	02	01	01	01	01	00	00

TABLE 3.—*Table for converting height (in millimeters) of flame in photograph to actual height.*

[Example: If height of flame as measured on film is 1.75 mm., locate 1 in column headed "Millimeters," and in same horizontal line locate value under column headed "0.75," which is 2.21, the desired height of flame in inches.]

Millimeters.	0	0.25	0.50	0.75
0	0	0.32	0.63	0.95
1	1.26	1.58	1.89	2.21
2	2.53	2.84	3.16	3.47
3	3.79	4.11	4.42	4.74
4	5.05	5.37	5.68	6.00
5	6.32	6.63	6.95	7.26
6	7.58	7.89	8.21	8.53
7	8.84	9.16	9.47	9.79
8	10.11	10.42	10.74	11.05
9	11.37	11.68	12.00	12.32
10	12.63	12.95	13.26	13.58
11	13.89	14.21	14.53	14.84
12	15.16	15.47	15.79	16.11
13	16.42	16.74	17.05	17.37
14	17.68	18.00	18.32	18.63
15	18.95	19.26	19.58	19.89
16	20.21	20.53	20.84	21.16
17	21.47	21.79	22.11	22.42
18	22.74	23.05	23.37	23.68
19	24.00	24.32	24.63	24.95
20	25.26	25.58	25.89	26.21

TABLE 4.—*Table for converting in explosion-by-influence tests the weights (grams) of cartridges[a] to specific-gravity values.*

[Example: If the specific gravity of a cartridge is 1.11, its weight 178.58=179.]

Specific gravity.	0	1	2	3	4	5	6	7	8	9
.5	80.44	82.05	83.66	85.27	86.88	88.49	90.09	91.70	93.31	94.92
.6	96.53	98.14	99.75	101.36	102.96	104.57	106.18	107.79	109.40	111.01
.7	112.62	114.23	115.84	117.44	119.05	120.66	122.27	123.88	125.49	127.10
.8	128.71	130.31	131.92	133.53	135.14	136.75	138.36	139.97	141.58	143.18
.9	144.79	146.40	148.01	149.62	151.23	152.84	154.45	156.06	157.66	159.27
1.0	160.88	162.49	164.10	165.71	167.32	168.93	170.53	172.14	173.75	175.36
1.1	176.97	178.58	180.19	181.80	183.41	185.01	186.62	188.23	189.84	191.45
1.2	193.06	194.67	196.28	197.88	199.49	201.10	202.71	204.32	205.93	207.54
1.3	209.15	210.76	212.36	213.97	215.58	217.19	218.80	220.41	222.02	223.63
1.4	225.23	226.84	228.45	230.06	231.67	233.28	234.89	236.50	238.11	239.71
1.5	241.32	242.93	244.54	246.15	247.76	249.37	250.98	252.58	254.19	255.80
1.6	257.41	259.02	260.63	262.24	263.85	265.46	267.06	268.67	270.28	271.89
1.7	273.50	275.11	276.72	278.33	279.93	281.54	283.15	284.76	286.37	287.98
1.8	289.59	291.20	292.81	294.41	296.02	297.63	299.24	300.85	302.46	304.07
1.9	305.68	307.28	308.89	310.50	312.11	313.72	315.33	316.94	318.55	320.16
2.0	321.76	323.37	324.98	326.59	328.20	329.81	331.42	333.03	334.63	336.24

[a] Diameter of cartridge, 1¼ inches; length of cartridge, 8 inches.

TABLE 5.—*Table for use in computing pressures developed by explosives in Bichel pressure gages.*

[Example: If spring used in gage is such that indicator record shows 0.32 mm. compression for every kilogram per square centimeter applied and if the indicator recor d gives a height of 33.75 mm., the table shows the corresponding pressure to be 105.47 kilograms per square centimeter.]

0.40 mm.=1 kg. per sq. cm.					0.60 mm.=1 kg. per sq. cm.					0.24 mm.=1 kg. per sq. cm.					0.32 mm.=1 kg. per sq. cm.				
	00	0.25	0.50	0.75		00	0.25	0.50	0.75		00	0.25	0.50	0.75		00	0.25	0.50	0.75
0	.00	.62	1.25	1.88	0	.00	.42	.83	1.25	0	.00	1.04	2.08	3.12	0	.00	.78	1.56	2.34
1	2.50	3.12	3.75	4.38	1	1.67	2.08	2.50	2.92	1	4.17	5.21	6.25	7.29	1	3.12	3.91	4.69	5.47
2	5.00	5.62	6.25	6.88	2	3.33	3.75	4.17	4.58	2	8.33	9.38	10.42	11.46	2	6.25	7.03	7.81	8.59
3	7.50	8.12	8.75	9.38	3	5.00	5.42	5.83	6.25	3	12.50	13.54	14.58	15.62	3	9.38	10.16	10.94	11.72
4	10.00	10.62	11.25	11.88	4	6.67	7.08	7.50	7.92	4	16.67	17.71	18.75	19.79	4	12.50	13.28	14.06	14.84
5	12.50	13.12	13.75	14.38	5	8.33	8.75	9.17	9.58	5	20.83	21.88	22.92	23.96	5	15.62	16.41	17.19	17.97
6	15.00	15.62	16.25	16.88	6	10.00	10.42	10.83	11.25	6	25.00	26.04	27.08	28.12	6	18.75	19.53	20.31	21.09
7	17.50	18.12	18.75	19.38	7	11.67	12.08	12.50	12.92	7	29.17	30.21	31.25	32.29	7	21.88	22.66	23.44	24.22
8	20.00	20.62	21.25	21.88	8	13.33	13.75	14.17	14.58	8	33.33	34.38	35.42	36.46	8	25.00	25.78	26.56	27.34
9	22.50	23.12	23.75	24.38	9	15.00	15.42	15.83	16.25	9	37.50	38.54	39.58	40.62	9	28.12	28.91	29.69	30.47
10	25.00	25.62	26.25	26.88	10	16.67	17.08	17.50	17.92	10	41.67	42.71	43.75	44.79	10	31.25	32.03	32.81	33.59
11	27.50	28.12	28.75	29.38	11	18.33	18.75	19.17	19.58	11	45.83	46.88	47.92	48.96	11	34.38	35.16	35.94	36.72
12	30.00	30.62	31.25	31.88	12	20.00	20.42	20.83	21.25	12	50.00	51.04	52.08	53.12	12	37.50	38.28	39.06	39.84
13	32.50	33.12	33.75	34.38	13	21.67	22.08	22.50	22.92	13	54.17	55.21	56.25	57.29	13	40.62	41.41	42.19	42.97
14	35.00	35.62	36.25	36.88	14	23.33	23.75	24.17	24.58	14	58.33	59.38	60.42	61.46	14	43.75	44.53	45.31	46.09
15	37.50	38.12	38.75	39.38	15	25.00	25.42	25.83	26.25	15	62.50	63.54	64.58	65.63	15	46.88	47.66	48.44	49.22
16	40.00	40.62	41.25	41.88	16	26.67	27.08	27.50	27.92	16	66.67	67.71	68.75	69.79	16	50.00	50.78	51.56	52.34
17	42.50	43.12	43.75	44.38	17	28.33	28.75	29.17	29.58	17	70.83	71.88	72.92	73.96	17	53.12	53.91	54.69	55.47
18	45.00	45.62	46.25	46.88	18	30.00	30.42	30.83	31.25	18	75.00	76.04	77.08	78.12	18	56.25	57.03	57.81	58.59
19	47.50	48.12	48.75	49.38	19	31.67	32.08	32.50	32.92	19	79.17	80.21	81.25	82.29	19	59.38	60.16	60.94	61.72
20	50.00	50.62	51.25	51.88	20	33.33	33.75	34.17	34.58	20	83.33	84.38	85.42	86.46	20	62.50	63.28	64.06	64.84
21	52.50	53.12	53.75	54.38	21	35.00	35.42	35.83	36.25	21	87.50	88.54	89.58	90.62	21	65.62	66.41	67.19	67.97
22	55.00	55.62	56.25	56.88	22	36.67	37.08	37.50	37.92	22	91.67	92.71	93.75	94.79	22	68.75	69.53	70.31	71.09
23	57.50	58.12	58.75	59.38	23	38.33	38.75	39.17	39.58	23	95.83	96.89	97.92	98.96	23	71.88	72.66	73.44	74.22
24	60.00	60.62	61.25	61.88	24	40.00	40.42	40.83	41.25	24	100.00	101.04	102.08	103.12	24	75.00	75.78	76.56	77.34
25	62.50	63.12	63.75	64.38	25	41.67	42.08	42.50	42.92	25	104.17	105.21	106.25	107.29	25	78.12	78.91	79.69	80.47
26	65.00	65.62	66.25	66.88	26	43.33	43.75	44.17	44.58	26	108.33	109.38	110.42	111.46	26	81.25	82.03	82.81	83.59
27	67.50	68.12	68.75	69.38	27	45.00	45.42	45.83	46.25	27	112.50	113.54	114.58	115.62	27	84.38	85.16	85.94	86.72
28	70.00	70.62	71.25	71.88	28	46.67	47.08	47.50	47.92	28	116.67	117.71	118.75	119.79	28	87.50	88.28	89.06	89.84
29	72.50	73.12	73.75	74.38	29	48.33	48.75	49.17	49.58	29	120.83	121.88	122.92	123.96	29	90.62	91.41	92.19	92.97
30	75.00	75.62	76.25	76.88	30	50.00	50.42	50.83	51.25	30	125.00	126.04	127.08	128.12	30	93.75	94.53	95.31	96.09

TABLE 5.—*Table for use in computing pressures developed by explosives in Bichel pressure gages*—Continued.

0.40 mm.=1 kg. per sq. cm.					0.60 mm.=1 kg. per sq. cm.					0.24 mm.=1 kg. per sq. cm.					0.32 mm.=1 kg. per sq. cm.				
	∞	0.25	0.50	0.75		00	0.25	0.50	0.75		00	0.25	0.50	0.75		00	0.25	0.50	0.75
31	77.50	78.12	78.75	79.38	31	51.67	52.08	52.50	52.92	31	129.17	130.21	131.25	132.29	31	96.88	97.66	98.44	99.22
32	80.00	80.62	81.25	81.88	32	53.33	53.75	54.17	54.58	32	133.33	134.38	135.42	136.46	32	100.00	100.78	101.56	102.34
33	82.50	83.12	83.75	84.38	33	55.00	55.42	55.83	56.25	33	137.50	138.54	139.58	140.62	33	103.12	103.91	104.69	105.47
34	85.00	85.62	86.25	86.88	34	56.67	57.08	57.50	57.92	34	141.67	142.71	143.75	144.79	34	106.25	107.03	107.81	108.59
35	87.50	88.12	88.75	89.38	35	58.33	58.75	59.17	59.58	35	145.83	146.88	147.92	148.96	35	109.38	110.16	110.94	111.72
36	90.00	90.62	91.25	91.88	36	60.00	60.42	60.83	61.25	36	150.00	151.04	152.08	153.12	36	112.50	113.28	114.06	114.84
37	92.50	93.12	93.75	94.38	37	61.67	62.08	62.50	62.92	37	154.17	155.21	156.25	157.29	37	115.62	116.41	117.19	117.97
38	95.00	95.62	96.25	96.88	38	63.33	63.75	64.17	64.58	38	158.33	159.38	160.42	161.46	38	118.75	119.53	120.31	121.09
39	97.50	98.12	98.75	99.38	39	65.00	65.42	65.83	66.25	39	162.50	163.54	164.58	165.62	39	121.88	122.66	123.44	124.22
40	100.00	100.62	101.25	101.88	40	66.67	67.08	67.50	67.90	40	166.67	167.71	168.75	169.79	40	125.00	125.78	126.56	127.34

TABLE 6.—*Table showing heights of charges for different specific gravities of cartridges*[a]*—small lead block tests.*

[Example: If the specific gravity of a given cartridge is 1.11, the table shows 7.9 as the requisite height of charge in centimeters.]

Specific gravity.	100-gram charge.										Specific gravity.	50-gram charge.									
	0	1	2	3	4	5	6	7	8	9		0	1	2	3	4	5	6	7	8	9
2.0	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.2	4.2	4.2	2.0	2.2	2.2	2.2	2.2	2.1	2.1	2.1	2.1	2.1	2.1
1.9	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.4	4.4	1.9	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.2
1.8	4.9	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.6	1.8	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3
1.7	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	1.7	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
1.6	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.2	5.2	1.6	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.6
1.5	5.8	5.8	5.8	5.7	5.7	5.7	5.6	5.6	5.6	5.5	1.5	2.9	2.9	2.9	2.9	2.8	2.8	2.8	2.8	2.8	2.8
1.4	6.3	6.2	6.2	6.1	6.1	6.0	6.0	6.0	5.9	5.9	1.4	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	2.9
1.3	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.4	6.3	1.3	3.4	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2
1.2	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	1.2	3.7	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.4	3.4
1.1	8.0	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.4	7.4	1.1	4.0	4.0	3.9	3.9	3.8	3.8	3.8	3.7	3.7	3.7
1.0	8.8	8.7	8.6	8.5	8.4	8.4	8.3	8.2	8.1	8.0	1.0	4.4	4.3	4.3	4.3	4.2	4.2	4.1	4.1	4.1	4.0
.9	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	9.0	8.9	.9	4.9	4.8	4.8	4.7	4.7	4.6	4.6	4.5	4.5	4.4
.8	11.0	10.8	10.7	10.6	10.4	10.3	10.2	10.1	10.0	9.9	.8	5.5	5.4	5.3	5.3	5.2	5.2	5.1	5.0	5.0	4.9
.7	12.5	12.4	12.2	12.0	11.9	11.7	11.5	11.4	11.2	11.1	.7	6.3	6.2	6.1	6.0	5.9	5.8	5.8	5.7	5.6	5.6
.6	14.6	14.4	14.1	13.9	13.7	13.5	13.3	13.1	12.9	12.7	.6	7.3	7.2	7.1	7.0	6.9	6.7	6.6	6.5	6.4	6.4
.5	17.5	17.2	16.9	16.5	16.2	15.9	15.7	15.4	15.1	14.9	.5	8.8	8.6	8.4	8.3	8.1	8.0	7.8	7.7	7.6	7.4
.4	21.9	21.4	20.9	20.4	19.9	19.5	19.1	18.7	18.3	17.9	.4	11.0	10.7	10.4	10.2	10.0	9.7	9.5	9.3	9.1	9.0

[a] Diameter of cartridges, 1½ inches.

TABLE 7.—*Table for converting inches of mercury into millimeters of mercury.*

		0	1	2	3	4	5	6	7	8	9
70	27	57	61	65	69	73	77	81	85	89	93
71	27	97	.....	.....	.....	.....	.....	.....	.....	.....	.....
71	28	.....	01	05	09	12	16	20	24	28	32
72	28	36	40	44	48	52	56	60	64	68	72
73	28	75	79	83	87	91	95	99	.....	.....	.....
73	29	.....	.....	.....	.....	.....	.....	.....	03	07	11
74	29	15	19	23	27	31	35	38	42	46	50
75	29	54	58	62	66	70	74	78	82	86	90
76	29	94	98	.....	.....	.....	.....	.....	.....	.....	.....
76	30	.....	.....	01	05	09	13	17	21	25	29
77	30	33	37	41	45	49	53	57	61	64	68
78	30	72	76	80	84	88	92	96	.....	.....	.....
78	31	.....	.....	.....	.....	.....	.....	.....	00	04	08
79	31	12	16	20	24	27	31	35	39	43	47

EXAMPLE SHOWING USE OF TABLE 7.

If 29.57 inches of mercury is to be converted into millimeters of mercury, as values from 29.58 to 29.55, inclusive, can be considered as equivalent to 751 millimeters of mercury, therefore 29.57, being within this range, is equal to 751 millimeters.

TABLE 8.—*Table for converting kilograms per square centimeter into millimeters of mercury.*

	0	1	2	3	4	5	6	7	8	9
1	736	810	883	957	1,030	1,104	1,178	1,251	1,325	1,398
2	1,472	1,546	1,619	1,693	1,766	1,840	1,914	1,987	2,061	2,134
3	2,208	2,282	2,355	2,429	2,502	2,576	2,650	2,723	2,797	2,870
4	2,944	3,018	3,091	3,165	3,238	3,312	3,386	3,459	3,533	3,606
5	3,680	3,754	3,827	3,901	3,974	4,048	4,122	4,195	4,269	4,342
6	4,416	4,490	4,563	4,637	4,710	4,784	4,858	4,931	5,005	5,078
7	5,152	5,226	5,299	5,373	5,446	5,520	5,594	5,667	5,741	5,814
8	5,888	5,962	6,035	6,109	6,182	6,256	6,330	6,403	6,477	6,550
9	6,624	6,698	6,771	6,845	6,918	6,992	7,066	7,139	7,213	7,286
10	7,360	7,434	7,507	7,581	7,654	7,728	7,802	7,875	7,949	8,022
11	8,096	8,170	8,243	8,317	8,390	8,464	8,538	8,611	8,685	8,758
12	8,832	8,906	8,979	9,053	9,126	9,200	9,274	9,347	9,421	9,494
13	9,568	9,642	9,715	9,789	9,862	9,936	10,010	10,083	10,157	10,230
14	10,304	10,378	10,451	10,525	10,598	10,672	10,746	10,819	10,893	10,966
15	11,040	11,114	11,187	11,261	11,334	11,408	11,482	11,555	11,629	11,702

EXAMPLE SHOWING USE OF TABLE 8.

To convert 5.1 kilograms per square centimeter to millimeters of mercury, find the value opposite 5 in the first column and under 1 in the third column, which is 3,754.

TABLE 9.—*TV_1 divided by PT_1.*

	0	1	2	3	4	5	6	7	8	9
280	0.01924	0.01917	0.01911	0.01904	0.01897	0.01891	0.01884	0.01877	0.01871	0.01864
290	.01858	.01852	.01845	.01839	.01833	.01826	.01820	.01814	.01808	.01802
300	.01796	.01790	.01784	.01778	.01772	.01767	.01761	.01755	.01749	.01744

METHOD OF USING TABLE 9.

The figures in the body of the table represent TV_1 divided by $PT_1=\frac{273\times15}{760\times T_1}$.

If T_1 be equal to 285, in the table find the factor opposite 280 in the first column and under 5 in the seventh column, which is 0.01891. This, multiplied by the absolute pressure P_1, gives the volume of the gas generated, reduced to standard conditions.

TABLE 10.—*Table for converting the volume of gas evolved by a given weight (grams) of explosive to the volume that would be evolved by 680 grams.*

	0	1	2	3	4	5	6	7	8	9
100	6.8000	6.7327	6.6667	6.6019	6.5385	6 4763	6.4151	6.3552	6.2963	6.2385
110	6.1818	6.1261	6.0714	6.0177	5.9649	5.9130	5.8621	5.8120	5.7627	5.7143
120	5.6667	5.6199	5.5738	5.5285	5.4839	5.4400	5.3968	5.3543	5.3125	5.2713
200	3.4000	3.3831	3.3663	3.3498	3.3333	3.3171	3.3010	3.2850	3.2692	3.2536
210	3.2381	3.2227	3.2076	3.1925	3.1776	3.1628	3.1481	3.1336	3.1193	3.1050
220	3.0909	3.0769	3.0631	3.0493	3.0357	3.0222	3.0088	2.9956	2.9825	2.9694
230	2.9565	2.9437	2.9310	2.9185	2.9060	2.8936	2.8814	2.8692	2.8571	2.8452
240	2.8333	2.8216	2.8099	2.7984	2.7869	2.7755	2.7642	2.7530	2.7420	2.7309

METHOD OF USING TABLE 10.

In the body of the table find the factor by which V must be multiplied to change the volume generated by the actual charge to the volume that would be formed by a charge of 680 grams.

TABLE 11.—*Table for converting centigrade degrees to Fahrenheit degrees or Fahrenheit degrees to centigrade degrees.*

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
00	1,000	2,000	3,000	°C.	0	1	2	3	4	5	6	7	8	9	00	1,000	2,000	3,000	°C.
				00	32	34	36	37	39	41	43	45	46	48					50
0	18	36	54	01	50	52	54	55	57	59	61	63	64	66	9	27	45	63	51
				02	68	70	72	73	75	77	79	81	82	84					52
				03	86	88	90	91	93	95	97	99							53
				03									00	02					53
1	19	37	55	04	04	06	08	09	11	13	15	17	18	20	10	28	46	64	54
				05	22	24	26	27	29	31	33	35	36	38					55
				06	40	42	44	45	47	49	51	53	54	56					56
				07	58	60	62	63	65	67	69	71	72	74					57
				08	76	78	80	81	83	85	87	89	90	92					58
				09	94	96	98	99											59
				09					01	03	05	07	08	10					59
2	20	38	56	10	12	14	16	17	19	21	23	25	26	28	11	29	47	65	60
				11	30	32	34	35	37	39	41	43	44	46					61
				12	48	50	52	53	55	57	59	61	62	64					62
				13	66	68	70	71	73	75	77	79	80	82					63
				14	84	86	88	89	91	93	95	97	98						64
				14										00					64
3	21	39	57	15	02	04	06	07	09	11	13	15	16	18	12	30	48	66	65
				16	20	22	24	25	27	29	31	33	34	36					66
				17	38	40	42	43	45	47	49	51	52	54					67
				18	56	58	60	61	63	65	67	69	70	72					68
				19	74	76	78	79	81	83	85	87	88	90					69
				20	92	94	96	97	99										70
				20						01	03	05	06	08					70
4	22	40	58	21	10	12	14	15	17	19	21	23	24	26	13	31	49	67	71
				22	28	30	32	33	35	37	39	41	42	44					72
				23	46	48	50	51	53	55	57	59	60	62					73
				24	64	66	68	69	71	73	75	77	78	80					74
				25	82	84	86	87	89	91	93	95	96	98					75
				25	00														75
5	23	41	59	26	00	02	04	05	07	09	11	13	14	16	14	32	50	68	76
				27	18	20	22	23	25	27	29	31	32	34					77
				28	36	38	40	41	43	45	47	49	50	52					78
				29	54	56	58	59	61	63	65	67	68	70					79
				30	72	74	76	77	79	81	83	85	86	88					80
				31	90	92	94	95	97	99									81
				31							01	03	04	06					81
6	24	42	60	32	08	10	12	13	15	17	19	21	22	24	15	33	51	69	82
				33	26	28	30	31	33	35	37	39	40	42					83
				34	44	46	48	49	51	53	55	57	58	60					84
				35	62	64	66	67	69	71	73	75	76	78					85
				36	80	82	84	85	87	89	91	93	94	96					86
				37	98														87
				37		00	02	03	05	07	09	11	12	14					87
7	25	43	61	38	16	18	20	21	23	25	27	29	30	32	16	34	52	70	88
				39	34	36	38	39	41	43	45	47	48	50					89
				40	52	54	56	57	59	61	63	65	66	68					90
				41	70	72	74	75	77	79	81	83	84	86					91
				42	88	90	92	93	95	97	99								92
				42								01	02	04					92
8	26	44	62	43	06	08	10	11	13	15	17	19	20	22	17	35	53	71	93
				44	24	26	28	29	31	33	35	37	38	40					94
				45	42	44	46	47	49	51	53	55	56	58					95
				46	60	62	64	65	67	69	71	73	74	76					96
				47	78	80	82	83	85	87	89	91	92	94					97
				48	96	98													98
				48			00	01	03	05	07	09	10	12					98
9	27	45	63	49	14	16	18	19	21	23	25	27	28	30	18	36	54	72	00
					0	1	2	3	4	5	6	7	8	9					

Directions for Using Table 11.

To convert centigrade degrees to Fahrenheit degrees:

1. Consider Fahrenheit temperature as consisting of four digits separated thus: 25°=0–02–5, or 3,169°=3–16–9.

2. Using the middle pair as a key, locate it in column E or T.

3. (*a*) In the same block as the key and in the column indicated by the first digit of the centigrade temperature, find the first part of the Fahrenheit equivalent. If the key is in column E, read the values in columns A to D; if the key is in column T, read the values in columns P to S.

(*b*) In the same horizontal line as the key and under the last digit of the centigrade temperature, as shown at the top of columns F to O, find the last two figures of the Fahrenheit equivalent.

Thus: 362° C.= 6–84=684° F.
3,169° C.=57–36=5,736° F.

To convert Fahrenheit degrees to centigrade degrees:

1. Separate the last two figures of the Fahrenheit temperature from the first two, making 1,916 read as 19–16; 39 as 0–39; 361 as 3–61.

2. (*a*) Using the first part as a key, look for it in columns A to D and P to S. Read the figure at the top of the column containing it as the first unit of the centigrade equivalent.

(*b*) In columns F to O, in the same horizontal block as the key, locate the last two figures of Fahrenheit values. Having found them, move horizontally to column E or T and read the two middle digits of the result. Column E is used if the key is found in any one of the columns A to D; column T is used if the key is found in any one of the columns P to S.

(*c*) Move vertically to the top of the column containing last two Fahrenheit digits, and get the final digit in digit of the centigrade temperature

Thus: 1,916=1–04–6=1,046.
39=0–00–4=4.
361=0–18–3=183.

Table 12.—*Table of equivalent temperatures.*

°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.
−25	−13	50	122	125	257	200	392	275	527	350	662	425	797
−20	− 4	55	131	130	266	205	401	280	536	355	671	430	806
−15	+ 5	60	140	135	275	210	410	285	545	360	680	435	815
−10	14	65	149	140	284	215	419	290	554	365	689	440	824
− 5	23	70	158	145	293	220	428	295	563	370	698	445	833
0	32	75	167	150	302	225	437	300	572	375	707	450	842
5	41	80	176	155	311	230	446	305	581	380	716	455	851
10	50	85	185	160	320	235	455	310	590	385	725	460	860
15	59	90	194	165	329	240	464	315	599	390	734	465	869
20	68	95	203	170	338	245	473	320	608	395	743	470	878
25	77	100	212	175	347	250	482	325	617	400	752	475	887
30	86	105	221	180	356	255	491	330	626	405	761	480	896
35	95	110	230	185	365	260	500	335	635	410	770	485	905
40	104	115	239	190	374	265	509	340	644	415	779	490	914
45	113	120	248	195	383	270	518	345	653	420	788	495	923

Values for Interpolation in Table 12.

°C.	°F.	°C.	°F.	°C.	°F.
1	1.8	4	7.2	7	12.6
2	3.6	5	9.0	8	14.4
3	5.4	6	10.8	9	16.2

All decimals are exact.

°F.	°C.	°F.	°C.	°F.	°C.
1	0.55	4	2.22	7	3.88
2	1.11	5	2.77	8	4.44
3	1.66	6	3.33	9	5.00

All decimals are repeating decimals.

TABLE 13.—*Table of miscellaneous equivalents.*

LENGTH, AREA, AND VOLUME.

1 cm.	=0.3937[a] inches,	log=	$\bar{1}$.59 517	1 inch	=2.54001 cm.,	log=	0.40 483
1 meter	=3.28083 ft.,		0.51 598	1 ft.	=0.30480 m.,		$\bar{1}$.48 402
1 sq. cm.	=0.15500 sq. in.,		$\bar{1}$.19 033	1 sq. in.	=6.4516 sq. cm.,		0.80 967
1 sq. meter	=10.7639 sq. ft.,		1.03 197	1 sq. ft.	=0.092903 sq. m.,		$\bar{2}$.96 803
1 cu. cm.	=0.061023 cu. in.,		$\bar{2}$.78 550	1 cu. in.	=16.387 cu. cm.,		1.21 450
1 cu. meter	=35.3145 cu. ft.,		1.54 795	1 cu. ft.	=0.028317 cu. m.,		$\bar{2}$.45 205
1 liter	=0.026417 gals.,		$\bar{1}$.42 188	1 gal.	=3.7854 liters,		0.57 812

MASS AND DENSITY.

1 kg.	=2.204622 lbs.,	log=	0.34 333	1 lb.	=0.453592 kg.,	log=	$\bar{1}$.65 667
1 gr./cm.^{3}	=62.4283 lbs./ft.^{3},		1.79 538	1 lb./ft.^{3}	=0.016018 gr./cm.^{3},		$\bar{2}$.20 462
Density of Hg	=0.491170 lbs./in.^{3} (at 32°),		$\bar{1}$.69 123	Density of Hg	=13.59545 gr./cm.^{3} (at 0° C.),		1.33 339
g (standard)	=32.1740 ft.-sec.$^{-2}$,		1.50 750	g (standard)	=980.665[a] cm. sec.$^{-2}$,		2.99 152

PRESSURE.

1 kg./cm.^{2}	=14.223 lbs./in.^{2},	log=	1.15 300	1 lb./in.^{2}	=0.070307 kg./cm.^{2},	log=	$\bar{2}$.84 700
("metric at-	=28.958 in. of hg,		1.46 177		=2.0360 in. of Hg,		0.30 877
mosphere")	=735.54 mm. of Hg,		2.86 661		=51.713 mm. of Hg,		1.71 360
	=32.84 ft. of H_2O (at 60°),		1.51 640		=27.71 in. of H_2O (at 60°),		1.44 258
	=0.9678 atmos,		$\bar{1}$.98 579		=0.068044 atmos,		$\bar{2}$.83 279
	=0.980665 [a] megabars,[b]		$\bar{1}$.99 152		=0.068947 megabars,[b]		$\bar{2}$.83 852
1000 mm. of	=1.3158 atmos,	log=	0.11 919	1 atmos,	=760[a] mm. of Hg,	log=	2.88 081
Hg,	=39.37[b] in. of Hg,		1.59 517		=29.921 in. of Hg,		1.47 598
	=44.65 ft. of H_2O (at 60°),		1.64 979		=33.93 ft. of H_2O (at 60°),		1.53 061
	=19.337 lbs./in.^{2},		1.28 640		=14.696 lbs./in.^{2},		1.16 721
	=1.3595 kg./cm.^{2},		0.13 339		=1.0333 kg./cm.^{2},		0.01 421
	=1.3333 megabars,[b]		0.12 491		=1.0133 megabars,[b]		0.00 573

ENERGY.

1 ft. lb.	=32.174 ft. poundals,	log=	1.50 750	1 ft. poundal	$=3.1081\times10^{-2}$ ft. lbs.,	log=	$\bar{2}$.49 250
	=0.13826 kg. meters,		$\bar{1}$.14 068	1 kg. meter	=7.2330 ft. lbs.,		0.85 932
	=1.3558 Joules,[c]		0.13 220	1 Joule [c]	=0.73756 ft. lbs.,		$\bar{1}$.86 780
	$=1.2861\times10^{-3}$ mean B. t. u.,		$\bar{3}$.10 929	1 mean B. t. u.	=777.5+ ft. lbs.,		2.89 071
	=0.3241 gr. calories,		$\bar{1}$.51 068	1 gr. calorie	=3.086 ft. lbs.,		0.48 932
	$=7.145\times10^{-4}$ lb. °C. cals.,		$\bar{4}$.85 402	1 lb. °C. cal.	$=1.3996\times10^{3}$ ft. lbs.,		3.14 598
	$=1.3381\times10^{-2}$ liter atmos,		$\bar{2}$.12 647	1 liter atmos.	=74.735 ft. lbs.,		1.87 353
	$=4.7253\times10^{-4}$ cu. ft. atmos,		$\bar{4}$.67 443	1 cu. ft. atmos.	$=2.1163\times10^{3}$ ft. lbs.,		3.32 557
	$=5.0505\times10^{-7}$ H. P. hours,		$\bar{7}$.70 333	1 H. P. hour	$=1.98\ [a]\times10^{6}$ ft. lbs.,		6.29 667
	$=5.1206\times10^{-7}$ chev. vap. hrs.,		$\bar{7}$.70 932	1 chev. vap. hr.	$=1.9529\times10^{6}$ ft. lbs.,		6.29 068
	$=3.7662\times10^{-4}$ watt hours,		$\bar{4}$.57 590	1 watt hour	$=2.6552\times10^{3}$ ft. lbs.,		3.42 410
1 Joule [c]	=0.10197 kg. meters,	log=	$\bar{1}$.00 848	1 kg. meter	=9.80665 [a] Joules,[c]	log=	0.99 152
	=0.73756 ft. lbs.,		$\bar{1}$.86 780	1 ft. lb.	=1.3558 Joules,		0.13 220
	=23.730 ft. poundals,		1.37 530	1 ft. poundal	$=4.2140\times10^{-2}$ Joules,		$\bar{2}$.62 470
	$=9.486\times10^{-4}$ mean B. t. u.,		$\bar{4}$.97 709	1 mean B.t.u.	$=1.0542\times10^{3}$ Joules,		3.02 291
	=0.2390 gr. calories,		$\bar{1}$.37 848	1 gr. calorie	=4.1834 Joules,		0.62 153
	$=5.270\times10^{-4}$ lb. °C. cal.,		$\bar{4}$.72 181	1 lb. °C. cal.	$=1.8976\times10^{3}$ Joules,		3.27 818
	$=9.8690\times10^{-3}$ liter atmos,		$\bar{3}$.99 427	1 liter atmos.	$=1.0133\times10^{2}$ Joules,		2.00 573
	$=3.4852\times10^{-4}$ cu. ft. atmos,		$\bar{4}$.54 223	1 cu. ft. atmos.	$=2.8693\times10^{3}$ Joules,		3.45 777
	$=3.7251\times10^{-7}$ H. P. hours,		$\bar{7}$.57 113	1 H. P. hour	$=2.6845\times10^{6}$ Joules,		6.42 887
	$=3.7767\times10^{-7}$ chev. vap. hrs.,		$\bar{7}$.57 711	1 chev. vap. hr.	$=2.6478\times10^{6}$ Joules,		6.42 288
	$=2.7778\times10^{-4}$ watt hours,		$\bar{4}$.44 370	1 watt hour	$=3.6\ [a]\times10^{-3}$ Joules,		3.55 630
1 B. t. u	$=2.5200\times10^{2}$ gr. calories,	log=	2.40 139	1 gr. calorie	$=3.9683\times10^{-3}$ B. t. u.,	log=	$\bar{3}$.59 861
	=0.5556 lb. °C. cal.,		$\bar{1}$.74 473	1 lb. °C. cal.	$=1.8\ [a]$ B. t. u.,		0.25 527
	=777.5+ ft. lbs.,		2.89 071	1 ft. lb.	$=1.2861\times10^{3}$ B. t. u.,		$\bar{3}$.10 929
	$=2.5016\times10^{4}$ ft. poundals,		4.39 822	1 ft. poundal	$=3.997\times10^{-5}$ B. t. u.,		$\bar{5}$.60 178
	$=1.0750\times10^{2}$ kg. meters,		2.03 139	1 kg. meter	$=9.302\times10^{-3}$ B. t. u.,		$\bar{3}$.96 861
	$=1.0542\times10^{3}$ Joules,[c]		3.02 291	1 Joule [c]	$=9.486\times10^{-4}$ B. t. u.,		$\bar{4}$.97 709
	=10.404 liter atmos,		1.01 719	1 liter atmos	$=9.612\times10^{-2}$ B. t. u.,		$\bar{2}$.98 281
	=0.3674 cu. ft. atmos,		$\bar{1}$.56 514	1 cu. ft. atmos	=2.722 B. t. u.,		0.43 486
	$=3.927\times10^{-4}$ H. P. hours,		$\bar{4}$.59 405	1 H. P. hour	$=2.547\times10^{3}$ B. t. u.,		3.40 595
	$=3.981\times10^{-4}$ chev. vap. hrs.,		$\bar{4}$.60 003	1 chev. vap. hr.	$=2.512\times10^{3}$ B. t. u.,		3.39 996
	=0.2928 watt hours,		$\bar{1}$.46 661	1 watt hour	=3.415 B. t. u.,		0.53 339
1 gr. cal.	$=3.9683\times10^{-3}$ mean B.t.u.	log=	$\bar{3}$.59 861	1 mean B.t.u	$=2.5200\times10^{2}$ gr. cal.,	log=	2.40 139
	$=2.2046\times10^{-3}$ lb. °C. cal.,		$\bar{3}$.34 333	1 lb. °C. cal.	$=4.5359\times10^{2}$ gr. cal.,		2.65 667
	=3.086 ft. lbs.,		0.48 932	1 ft. lb.	=0.3241 gr. cal.,		$\bar{1}$.51 068
	=99.27 ft. poundals,		1.99 682	1 ft. poundal	$=1.0073\times10^{-2}$ gr. cal.,		$\bar{2}$.00 318
	=0.4266 kg. meters,		$\bar{1}$.63 000	1 kg. meter	=2.3442 gr. cal.,		0.37 000
	=4.1834 Joules,[c]		0.62 153	1 Joule [c]	=0.2390 gr. cal.,		$\bar{1}$.37 848
	$=4.1286\times10^{-2}$ liter atmos,		$\bar{2}$.61 579	1 liter atmos.	=24.22 gr. cal.,		1.38 421
	$=1.4580\times10^{-3}$ cu. ft. atmos,		$\bar{3}$.16 374	1 cu. ft. atmos,	$=6.859\times10^{2}$ gr. cal.,		2.83 626
	$=1.5583\times10^{-6}$ H. P. hours,		$\bar{6}$.19 265	1 H. P. hour	$=6.417\times10^{5}$ gr. cal.,		5.80 735
	$=1.5800\times10^{-6}$ chev. vap. hrs.,		$\bar{6}$.19 864	1 chev. vap. hr.	$=6.329\times10^{5}$ gr. cal.,		5.80 135
	$=1.1621\times10^{-3}$ watt hours,		$\bar{3}$.06 522	1 watt hour	$=8.605\times10^{2}$ gr. cal.,		2.93 478

[a] Exact value, by definition. [b] 1 megabar = 10^6 dynes per sq. cm. [c] 1 Jule = 10^7 ergs.

POWER.

(1 horsepower (H. P.) is 550 ft. lbs. per second; 1 watt is 1 Joule per second, or 10^7 ergs per second; 1 kilowatt (K. W.) is 1000 watts; 1 cheval-vapeur, or pferdegraft, or "continental horsepower," is 75 kg. meters per second; 1 poncelet is 100 kg. meters per second.]

1 K. W.	= 1.3410 H. P.,	log = 0.12 743	1 H. P.	= 0.7457 K. W.,	log = $\bar{1}$.87 257
	= 1.3597 chev. vap.,	0.12 343		= 1.0139 chev. vap.,	0.00 599
	= 1.0197 poncelets,	0.00 349		= 0.7604 poncelets,	$\bar{1}$.88 105
	= 737.56 ft. lbs./sec.,	2.86 780		= 550 ft. lbs./sec.,	2.74 036
	= 101.97 kg. m./sec.,	2.00 848		= 76.040 kg. m./sec.,	1.88 104
	= .9486 B. t. u./sec.,	$\bar{1}$.97 709		= 0.7074 B. t. u./sec.,	$\bar{1}$.84 965
	= 239.04 gr. cals./sec.,	2.37 848		= 178.25 gr. cal./sec.,	2.25 104

TABLE 14.—*Table showing the limit of variation (percentage of total explosive) for various quantities of moisture (percentage) arranged for "tolerances" promulgated July 1, 1915, by the Bureau of Mines.*

[Arranged by J. E. Tiffany.]

Quantity of moisture.		Limit of variation of total explosive.	Quantity of moisture.		Limit of variation of total explosive.
From—	To—		From—	To—	
Per cent.	*Per cent.*	*Per cent.* ±	*Per cent.*	*Per cent.*	*Per cent.* ±
0.00	0.10	1.50	5.11	5.30	2.80
.11	.30	1.55	5.31	5.50	2.85
.31	.50	1.60	5.51	5.70	2.90
.51	.70	1.65	5.71	5.90	2.95
.71	.90	1.70	5.91	6.10	3.00
.91	1.10	1.75	6.11	6.30	3.05
1.11	1.30	1.80	6.31	6.50	3.10
1.31	1.50	1.85	6.51	6.70	3.15
1.51	1.70	1.90	6.71	6.90	3.20
1.71	1.90	1.95	6.91	7.10	3.25
1.91	2.10	2.00	7.11	7.30	3.30
2.11	2.30	2.05	7.31	7.50	3.35
2.31	2.50	2.10	7.51	7.70	3.40
2.51	2.70	2.15	7.71	7.90	3.45
2.71	2.90	2.20	7.91	8.10	3.50
2.91	3.10	2.25	8.11	8.30	3.55
3.11	3.30	2.30	8.31	8.50	3.60
3.31	3.50	2.35	8.51	8.70	3.65
3.51	3.70	2.40	8.71	8.90	3.70
3.71	3.90	2.45	8.91	9.10	3.75
3.91	4.10	2.50	9.11	9.30	3.80
4.11	4.30	2.55	9.31	9.50	3.85
4.31	4.50	2.60	9.51	9.70	3.90
4.51	4.70	2.65	9.71	9.90	3.95
4.71	4.90	2.70	9.91	10.00	4.00
4.91	5.10	2.75			

TABLE 15.—*Table showing the limit of variation (percentage of total explosive) for various quantities of constituent, as arranged for curve promulgated July 1, 1915, by the Bureau of Mines.*

[Arranged by Spencer P. Howell.]

Quantity of constituent.		Limit of variation of total explosive.	Quantity of constituent.		Limit of variation of total explosive.
From—	To—		From—	To—	
Per cent.	*Per cent.*	*Per cent.* ±	*Per cent.*	*Per cent.*	*Per cent.* ±
0.00	0.50	1.00	30.51	31.50	2.17
.51	1.50	1.05	31.51	32.50	2.20
1.51	2.50	1.10	32.51	33.50	2.23
2.51	3.50	1.15	33.51	34.50	2.26
3.51	4.50	1.20	34.51	35.50	2.29
4.51	5.50	1.25	35.51	36.50	2.31
5.51	6.50	1.30	36.51	37.50	2.34
6.51	7.50	1.35	37.51	38.50	2.37
7.51	8.50	1.40	38.51	39.50	2.40
8.51	9.50	1.45	39.51	40.50	2.43
9.51	10.50	1.50	40.51	41.50	2.46
10.51	11.50	1.53	41.51	42.50	2.49
11.51	12.50	1.57	42.51	43.50	2.51
12.51	13.50	1.60	43.51	44.50	2.54
13.51	14.50	1.63	44.51	45.50	2.57
14.51	15.50	1.67	45.51	46.50	2.60
15.51	16.50	1.70	46.51	47.50	2.63
16.51	17.50	1.73	47.51	48.50	2.66
17.51	18.50	1.77	48.51	49.50	2.69
18.51	19.50	1.80	49.51	50.50	2.71
19.51	20.50	1.83	50.51	51.50	2.74
20.51	21.50	1.87	51.51	52.50	2.77
21.51	22.50	1.90	52.51	53.50	2.80
22.51	23.50	1.93	53.51	54.50	2.83
23.51	24.50	1.97	54.51	55.50	2.86
24.51	25.50	2.00	55.51	56.50	2.89
25.51	26.50	2.03	56.51	57.50	2.91
26.51	27.50	2.06	57.51	58.50	2.94
27.51	28.50	2.09	58.51	59.50	2.97
28.51	29.50	2.11	59.51	60.00	3.00
29.51	30.50	2.14			

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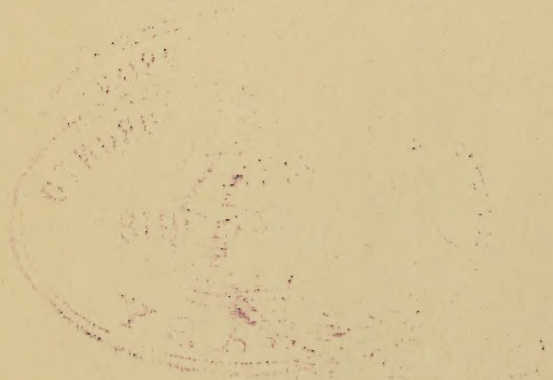
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